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ABSTRACT

A study was made to determine the feasibility, infeasibility, or deferred feasibility of adapting a computer-assisted instruction (CAI) system to an existing non-automated program for providing keyboard experiences to elementary school children. A systematic task-by-task approach was adopted for the study: learning objectives were assessed, the present keyboard experience program (in Wichita Public Schools) was studied at first hand, an analysis was made of the applicability of existing computer-related technology, preliminary design alternatives were formulated, and designs were subjected to feasibility testing and evaluation. Three computer-based designs were developed, tested, and evaluated: an instructional management system, an advanced CAI system, and an intermediate approach. Significant conclusions which emerged from the study include that a CAI keyboard experiences system is susceptible only in part to the solutions being found for CAI systems in other educational areas, that the interactive CAI keyboard systems is most technologically feasible but is not economically feasible, and that a keyboard experience program involving automated non-computerized methods for individualized instruction is both economically and educationally feasible, and should be implemented. (Author/SP)

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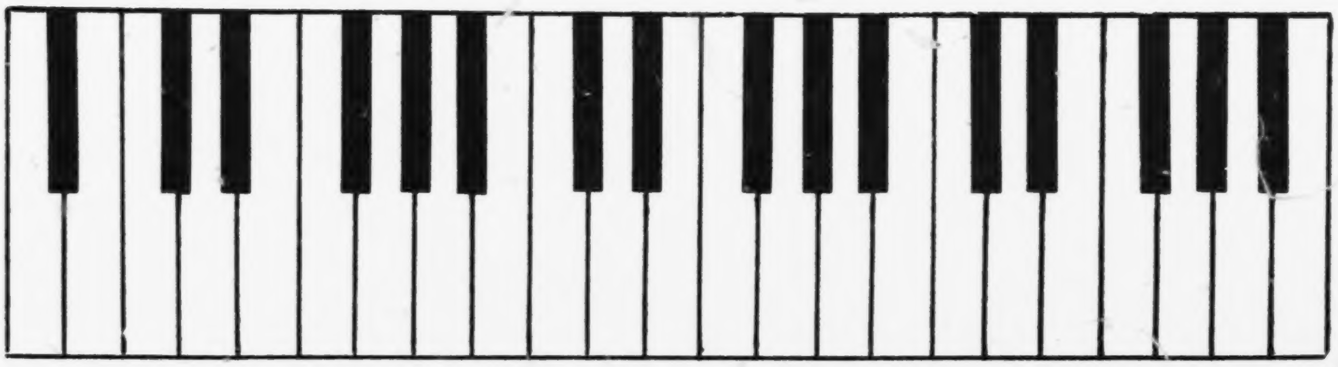
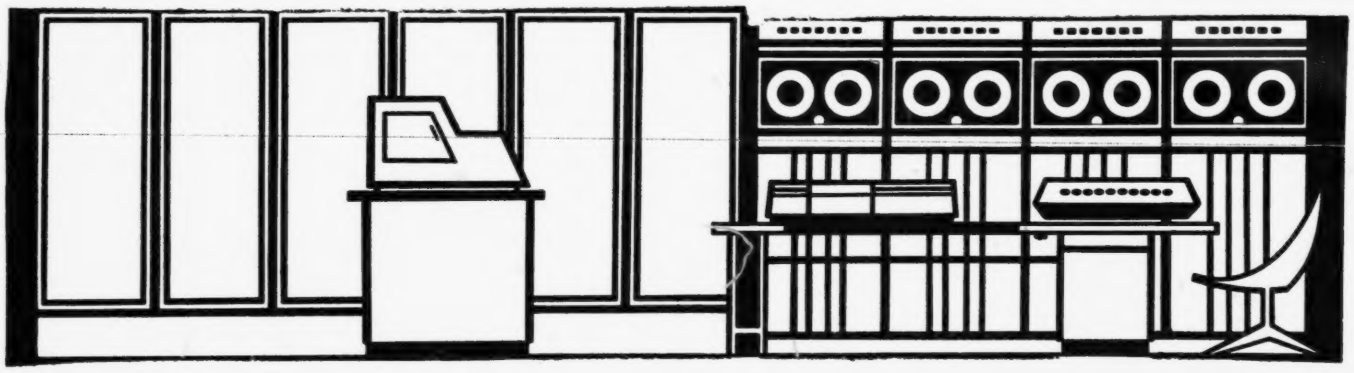


FEASIBILITY OF COMPUTER - ASSISTED ELEMENTARY KEYBOARD MUSIC INSTRUCTION

MARCH 1970



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Final Report

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Feasibility of Computer-Assisted Elementary Keyboard Music Instruction

TM-WD-347

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In Cooperation With

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and

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SUMMARY

The newly evolving technology of computer-assisted instruction (CAI) appears certain to have a major impact on education in the next few years. It offers to bring high-quality, individualized learning experiences to large numbers of students at costs comparable to those of conventional non-individualized instruction. Although many technical and economic problems must be solved before this promise can be realized, current indications are that solution is only a matter of time. The present study assesses the promise of CAI for elementary keyboard music education. It finds great potential value. Costs at the present are prohibitive, but should decline within a few years to economically feasible levels. In the meantime, new methods of automated but non-computer-based keyboard instruction appear very worthwhile pursuing. They would be inexpensive and immediately beneficial, as well as being stepping stones to future CAI methods.

The impetus for the present project was the enthusiastic interest of the Wichita (Kansas) Public School System in exploring the possibilities of computerizing its nationally known mobile keyboard experience program for elementary-school children in deprived areas. The effort was subsequently undertaken as a cooperative enterprise by the Wichita Public Schools, The Wurlitzer Company, and System Development Corporation. The study goal was to determine the feasibility, infeasibility, or deferred feasibility of a computer-assisted instruction system for keyboard experience.

The value of keyboard experience programs has long been recognized by music educators. The piano is generally conceded to be the most versatile instrument for learning musical relationships. It encompasses harmony, rhythm, melody, and musical form; and basic performance skills can be quickly attained. Also, it involves a student's auditory, visual, tactile, and kinesthetic senses--all crucial in reinforcing musical experiences. Finally, many music educators consider the piano to have the greatest carryover into adult life.

A systematic task-by-task approach was adopted for the study: learning objectives were assessed; the present keyboard experience program in Wichita was studied at first hand; an analysis was made of the applicability of existing computer-related technology; preliminary design alternatives were formulated; and designs were subjected to feasibility testing and evaluation. Expert opinions were also sought from educators prominent in innovative efforts in music instruction, and a thorough examination was made of pertinent

literature in the field. Working papers developed during the study were freely circulated to solicit comments and advice.

An early finding was an almost complete lack of precedent for keyboard CAI, even though considerable work has been done in computer-generated music and computer analysis of music. It follows that computer-to-piano interface hardware, and software for interpreting keyboard responses, do not exist--they must be developed. A part of the study was concerned with seeking solutions in those areas.

Three computer-based designs were developed which seemed particularly promising--an instructional management system, an advanced CAI system, and an intermediate approach. These designs were tested and evaluated--in part through simulated trials with third-grade students in Wichita--and expected costs were estimated.

Although feasibility testing of design alternatives was necessarily confined to a short period, it was clearly evident to all observers that children participating in the testing made remarkably fast progress. The progress was all the more remarkable in view of the lesson materials used, which were preliminary, untested versions. Also noteworthy was the almost complete lack of correlation between the students' performance and their Iowa Test of Basic Skills composite percentile ratings (which do not measure music aptitude, knowledge, or interest). As a group, students with low percentile ratings performed about as well as those with high percentile ratings.

Several significant conclusions emerged from this study. First, since music is overwhelmingly aural and aesthetic, a CAI keyboard experience system is susceptible only in part to the solutions being found and adopted for CAI systems in other educational areas. In the latter case, the medium of instruction is verbal or textual--the kind of interaction that can be effectively carried out with typewriter or TV-like terminals. The "grammar" of music (notation, for example) is, of course, directly susceptible to those techniques. But the grammar is only a symbolic representation of what must be (if it is to be of musical value) an aural experience that lies largely in the aesthetic domain.

Second, an interactive CAI keyboard experience system was found to be unquestionably technologically feasible and was judged to be the most effective system attainable. But, as is the case with other CAI systems already developed, implementation is not economically feasible on a broad scale at the present time. In addition, substantial developmental costs will need to be incurred to resolve system requirements unique to keyboard experience, even though much can and should be borrowed from the technology already developed and being developed for other CAI systems.

Third, it was concluded that the mobile keyboard experience program now in operation in Wichita, despite its demonstrated value in a specialized setting, is itself not economically feasible for implementation in elementary schools on a large scale. Also the program is operated in the traditional lock-step mode, in which opportunities for individualized learning are minimal. However, an alternative approach, involving automated non-computerized methods, was devised during the project and appears to permit effective, individualized, low-cost keyboard instruction.

The resulting recommendations are first, that full-scale development of an interactive CAI keyboard experience system should be deferred. Instead, a sustained experimental research and development effort should be made over the next three years in areas uniquely the province of keyboard experience. This nonduplicative research and development effort, coupled with the capturing of relevant technological and cost breakthroughs in other CAI systems during that time period, can then be applied to the design, development, and implementation of a full-scale experimental CAI keyboard experience system by around 1975.

Second, development and testing of an automated, non-computer-based keyboard experience program for individualized instruction should begin immediately. Widespread implementation of such a system appears to be currently feasible at low cost and would have great educational value.

I. INTRODUCTION

A. Project Purpose and Background

This document is the final report of a thirteen month study performed by System Development Corporation (SDC), under contract to the Arts and Humanities Program, National Center for Educational Research and Development, U.S. Office of Education. The study's aim was to determine the feasibility of individualized computer-assisted instruction (CAI) in keyboard experience music education at the elementary-school level. The project was undertaken in cooperation with the Wichita (Kansas) Public Schools and The Wurlitzer Company.

The impetus for the study came from the interest of the Wichita Public Schools in exploring the possibilities of computerizing its mobile keyboard experience program for elementary-school children in deprived areas. That program is now in its fifth year of operation and has attracted nationwide attention. Instruction is given in two mobile vans, in each of which are housed 22-23 electronic pianos (Figure 1). Approximately 1800 students (principally third-grade level) from 10 ESEA Title I schools participated in the program during the 1968-1969 school year on a once-a-week basis.

The Wichita keyboard program has clearly established its value for music education. However, it reaches comparatively few children; it requires teachers to repeat each lesson as many as fifty times in a week; it allows for little if any response to the needs, interests, and activities of individual children; and it is rather expensive. In this situation it becomes highly pertinent to ask whether the newly evolving technology of computer-assisted instruction can help bring a keyboard experience program to more children, reduce teacher tedium, individualize instruction, and lower costs.

This project, accordingly, sought to be both imaginative and practical, with the goal of determining the feasibility, infeasibility, or deferred feasibility of a CAI keyboard experience system. Three aspects of feasibility were considered: (1) technological feasibility--can such a system be engineered and built?; (2) economic feasibility--can school districts afford such a system?; and (3) educational feasibility--can instructional materials be prepared, presented under computer control, and managed in a real school situation in such a way that children will learn?

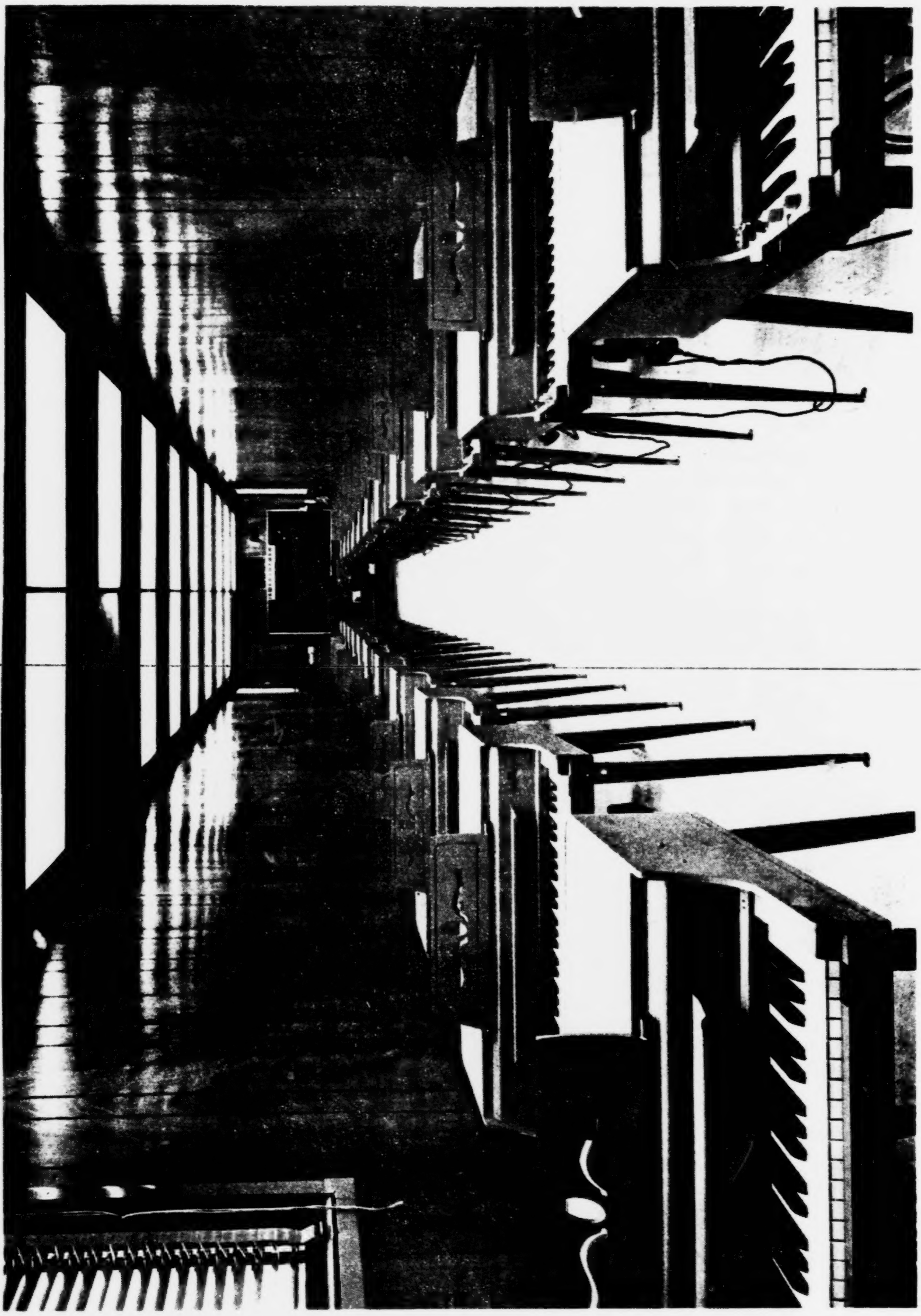

Figure 1. Van Interior View

Of great importance was the feasibility of extending individualized keyboard experiences to large student populations. There must exist a reasonable expectation that any proposed system can be implemented on a broad scale. If only small-scale implementation is possible, then a system is feasible in only the most narrow sense.

Considerable importance was also attached to the purpose of a keyboard experience program. The purpose of such a program is not to develop pianists, but rather to exploit the piano keyboard as a resource tool in learning musical concepts. This is not an idle consideration because it bears directly on the technology and methodology to be considered for a computer-based system.

A *de facto* assumption was made that keyboard instruction is a viable medium for learning music concepts--with or without a computer. The case for keyboard experience as an integral part of a music program has been made by many music educators. A small sample of their views follows:

> In contrast to group (class) piano instruction where specific pianistic skills are taught, (keyboard experience) uses the piano as a resource instrument to highlight musical understanding. It gives concrete examples of melodic movement and chord structure which the child can hear with his ears, see with his eyes, and feel with his fingers.[1]
>
> The piano keyboard is used to teach basic fundamentals of music because the piano is the "most universal and indispensable medium of music."[2] As an instrument it can encompass harmony, melody, rhythm and form allowing the student to experience a wide range of musical relationships. The piano is a tuned instrument and as such the student need not encounter the problem of producing a correct pitch as he would with string or wind instruments. Music fundamentals can more readily be learned

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[1] Pace, Robert, "Keyboard Experience in the Classroom," *Music Educators Journal*, Feb-Mar, 1960, p. 44.

[2] Hutcheson, Ernest, *The Literature of the Piano*, (N.Y. 1948), p.3.

> because the student's auditory, visual, tactile, and kinesthetic senses reinforce each other. Piano affords the most practical and rapid means of building skills in listening and reading music, of developing knowledge and understanding, and of supplying a foundation for other musical study.[1]
>
> While all children in the Wichita public schools do participate in regular music classes, it is not always possible for each pupil to arrive at an awareness of genuine musical accomplishment. The piano, because of its wide tonal range and simplicity in producing a sound, lends itself readily for experimentation by children. Compared with the complex fingering necessary to play other instruments, a limited, elementary knowledge of the piano keyboard is easily acquired, thus enabling the child in one or two lessons to play simple tunes. Not only is a successful experience realized from the outset as the child finds himself on the way toward gaining the much needed confidence in his own ability, but also he is learning to communicate his feelings and emotions through music.[2]

Implicit in the foregoing remarks is the need for children to be active participants in the learning process:

> Growth...is an active, not a passive process. A child learns to sing by singing; he learns to move expressively by moving; he learns to play an instrument by manipulating a given instrument; and he learns to think in musical terms by experiencing music in as many appealing and enjoyable ways as possible.[3]

---

[1] Teaching Piano in Classroom and Studio, Eds. Helen Robinson and Richard L. Jarvis, MENC 1967, p. 1.

[2] Bodecker, Louis K., Teaching Music Through Keyboard Experiences to Third Grade Children in Selected Impoverished Elementary Schools, University Microfilms, Inc., Ann Arbor, Michigan (Order No. 69-2827), 1968, p. 8.

[3] Hartsell, O.M., "Teaching Music in the Elementary School: Opinion and Comment," Association for Supervision and Curriculum Development, NEA, 1963, p. 3.

B. Musical Concept Teaching through Keyboard Mediation[1]

1. Implications of Musical Concepts. A musical concept is a complex of several interrelated subconcepts. The subconcepts are not mutually exclusive nor are they exclusively a part of any single concept. A complete understanding of a concept is probably never possible by any individual because the perception of the interrelationships is never fully developed. Within any given musical work, a whole new set of these interrelationships may be established.

Although musical concepts cannot be conclusively taught, with each new musical experience a greater depth of understanding can take place. The learning of concepts is cyclic--each time there is a new learning sequence involving a related concept, it changes the state of all others. The component parts of any single concept also are not identifiable in isolation--they, too, are interrelated.

In the structure of music (as in other subject areas), concepts are unequal in complexity. The "phrase" is a highly complex concept because it includes subconcepts and elements from so many other complex concepts (harmony, form, and so on). The structure of music could probably be classified by a taxonomy of concepts arranged in rank order of complexity within categories.

2. Concept Teaching. Teaching concepts is the process of causing the student to perceive the constituent elements of the concept which are closest to the center of the concept model in such a way as to build relationships among them. The manner in which this causes optimum learning to occur may be varied according to the student's previously acquired perceptual framework of the subconcepts.

The teaching task is theorized to be:

a. Identify the essential elements of the concept to be taught (essential elements that constitute the concept).

b. Determine which of the elements the student already understands (elements which have been taught in other concept teaching-learning tasks).

---

[1] This section is adapted from material furnished by Dr. Raynold Allvin, Oakland University, Michigan

c. Design conditions which cause the student to learn the missing essential elements.

d. Design strategies which cause the student to attend to the relationships among constituent elements.

3. Learning Flow. The use of kinesthetic actions (keyboard experience) as means of developing musical concepts suggests three sense modality flow diagrams (Figure 2). These are derived from the three sense models possible in music teaching and learning. The transfer of information or learning from one mode to another requires that a set of teaching strategies optimum to learning be used; for example, the sequence of tasks in Flow II (Figure 2) passes through two sets of strategies (visual to kinesthetic; kinesthetic to aural) to reach a point at which conceptualization may take place (aural to concept). Maximum conceptualization occurs, if it occurs at all, only when each of the links has maximally effected transfer. Failure of any link in the flow will undoubtedly result in a significant drop in transfer quality and reduce chances that the concept desired will be properly structured.

The process of structuring concepts from audio signals or kinesthetic acts is, of course, the center of keyboard-mediated music instruction. Of the three music teaching-learning sequence flows outlined in Figure 2, only I and II have validity--III is discounted. The use of a keyboard to develop a visual pattern and then transfer that pattern to audio for the purpose of building musical concepts seems a far too complex procedure for value--possibilities of interference are too great. If this flow is desirable, the keyboard portion is best dropped and teaching started with visual to audio strategies. The two remaining sequences of tasks place the keyboard use much closer to the perception of the terminal concept.

Having discounted task flow III, concentration on teaching-learning strategies centers on kinesthetic-to-audio schemes.

4. The "Audio to Concept" Transition. As previously stated, musical concepts are products of aural perception. The substance of the concept resides in and is transferred by the audio signal. The concept of "phrase", for instance, does not exist without the perception of phrases in an audio signal, nor can the "phrase" concept be communicated without a common experiential background.

It is undoubtedly true that a musical concept could be taught and learned by providing a wide sample of audio signals, with the concept present in each. However, this would take a great deal of time of both teacher and learner. For greater effectiveness, the

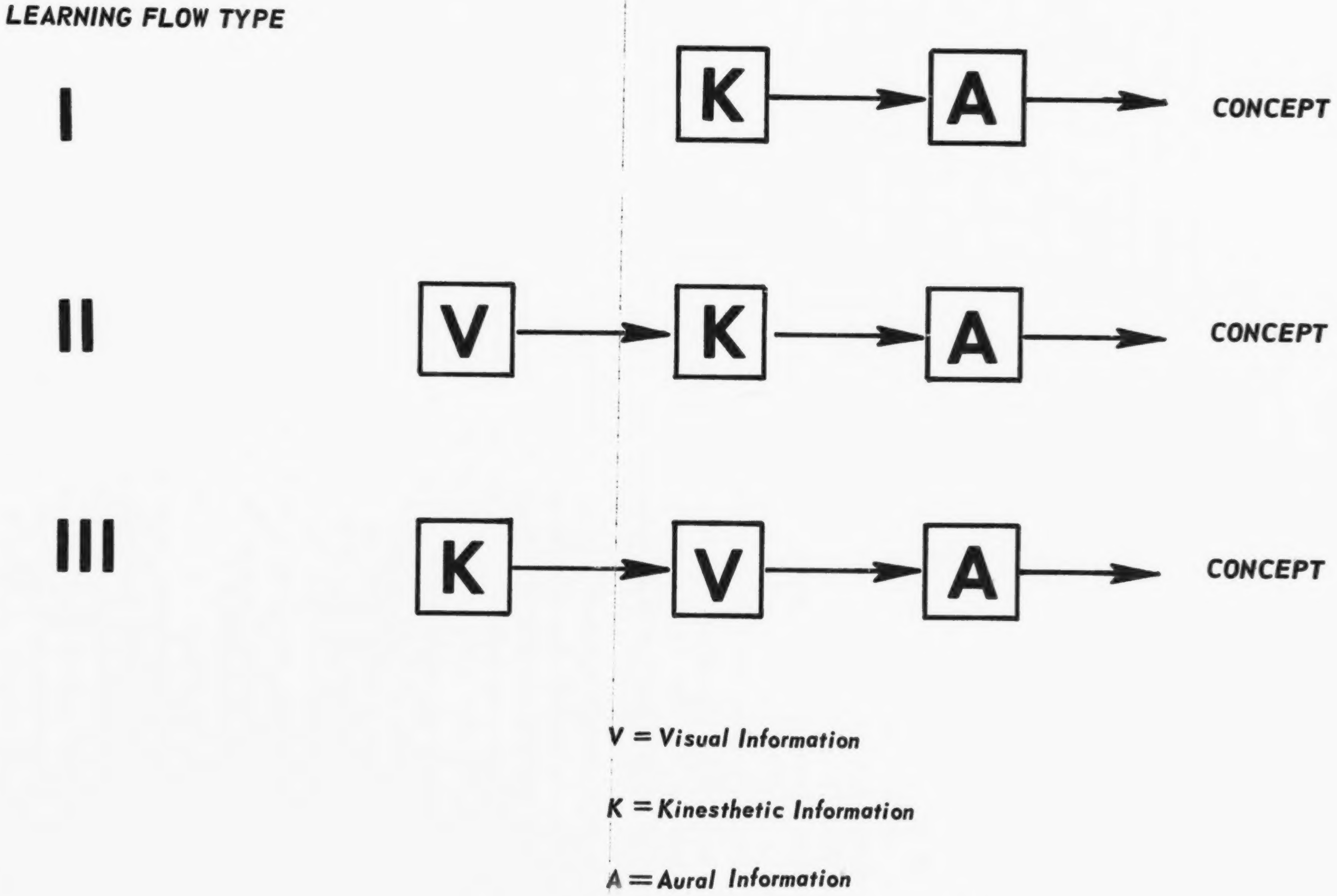
LEARNING FLOW TYPE
I
K
A
CONCEPT
II
V
K
A
CONCEPT
III
K
V
A
CONCEPT
V = Visual Information
K = Kinesthetic Information
A = Aural Information

Figure 2. Learning Flow Using Keyboard Mediation

presentation of the audio signal laden with the concept may be reinforced by other modal means (visual, verbal, or kinesthetic) to make the perception more efficient. The function of these reinforcers is to focus on the desired concept and to exclude interference caused by other concepts also residing in the signal.

A concept cannot be fragmented and presented piecemeal to the student--the signal contains the total concept or it does not. The signal cannot transfer part of a concept.

Most concept teaching in music relies on strengthening the perceptual skills of the student so that he is able to perceive the concept. As the student grows in discrimination skill, he is able to "hear" the concept. Without this, any teaching-learning system is at best asking for rote memorization of someone's verbal or graphic representation, rather than for real musical concept learning.

Reinforcement of the concept by perceptual modes other than audio is necessary to optimize learning. The reinforcement is probably most effective when it occurs concurrent with concept presentation. If that is not possible, then reinforcement should be in immediate temporal proximity.

5. Keyboard-Mediated Music Assumptions

a. Musical concepts are developed through the audio mode only. Other modes may be used to increase awareness of and attention to the audio, but cannot develop the concept by themselves.

b. All other modes are effective in heightening perception of audio.

c. The function of keyboard skills in developing musical understanding is to reinforce the audio-mediated concepts.

d. A concept is comprised of number of factors (elements or subconcepts), the majority of which are identifiable. The interrelationship of the factors is the substance of the concept.

6. Keyboard-Mediated Strategies. The keyboard offers two major functional purposes in developing musical concepts: (1) a means of creating the audio signal which carries the concept, and (2) a kinesthetic means of reinforcement.

The problems of instruction by such methodology are mainly two:

a. How does evaluation occur of whether the concept has been grasped? The response of the student occurs before or during the hoped-for perception. Immediate evaluation in behavioral terms is impossible under these conditions. The evaluation must therefore come not as direct observation of an act but as an evaluation of subsequent and sometimes partly unrelated acts.

b. Since direct evaluation is not possible (as an integral part of a teaching-learning strategy, as used in stimulus-response systems), how are subsequent teaching routines determined and reinforcement schedules established?

Answers to these problems need to be worked out during detailed design and production of instructional materials. Caution will have to be exercised to keep evaluation in proper perspective. Indirect indicators of concept perception are not to be evaluated for their own sake, but only as more or less probable signs of musical concept learning.

C. Related Studies

Only two pertinent CAI studies in music were found. These, and the work of Dr. Walter Ihrke, University of Connecticut, are briefly described below.

1. CAI Clarinet Study. Dr. Ned Deihl and his associates at Pennsylvania State University recently completed a feasibility study of CAI clarinet instruction involving articulation, phrasing, and rhythmic playing. During pilot trials, 14 clarinetists participated. Hour-long sessions were conducted, twice a week for eight weeks. Both on-line and off-line techniques were used. An IBM 1500 Instructional System was used for on-line sessions. In that configuration, students viewed lesson materials and made responses via an image projector and a combined cathode-ray-tube, light pen, and keyboard terminal. A random-access audio response unit was used to present recorded models. The system used did not "listen" to the students' playing; that is, no computer interpretation and analysis of the playing was attempted. Essentially, the computer system presented master models as feedback for the student to compare with his recorded versions. A Uher tape recorder was used for off-line instruction.[1]

---

[1] Deihl, Ned C., Development and Evaluation of Computer-Assisted Instruction in Instrumental Music, The Pennsylvania State University, Report No. R-24, September 1969.

2. IBM-Stanford University Experimentation. Drs. Raynold Allvin and Wolfgang Kuhn collaborated with IBM in some interesting experiments. The first involved voice pitch training, in which an IBM 1620 computer and a specially developed automatic pitch discriminator and CAI language were used.[1] The pitch discriminator extracted musical pitches sung by a student; these pitches were then compared with a set of prestored pitches, and the resultant evaluation was presented to the student via a typewriter-like terminal. A printout illustrating the instruction procedures used is shown in Figure 3.

A second experiment involved four components of basic musicianship: (1) ear training, (2) music notation, (3) elementary analysis, and (4) rhythm discrimination.[2] The IBM 1500 Instructional System was used in this project.

3. Automated Rhythm Trainer. Dr. Walter Ihrke, University of Connecticut has performed extensive work in rhythm training using non-computer-based automated techniques.[3] An electronic system is used which involves three components: a tape recorder using two channels simultaneously; a keyboard which produces tones and an electronic signal whenever a key is played; and an electronic rhythm monitor. The electronic rhythm monitor receives signals from the keyboard and from one of the tape channels, compares them, and reports to the student the acceptability of his response by means of signal lights. Both "early" or "late" responses will cause the appropriate light to light up and remain lit until a correct response is made. As the student receives immediate feedback, this arrangement allows a full flow of information from student to system and return.

The second tape channel may be used to provide a background to the student's response. Background music can maintain a steady tempo, provide rhythmic complications as the student plays simple combinations, or additionally provide a number of flexible musical backgrounds, including a full symphony orchestra.

---

[1] Kuhn, W. E. and Allvin, R. L., "Computer-Assisted Teaching: A New Approach to Research in Music," Journal of Research in Music Education, Winter 1967.

[2] Allvin, R. L., Computer-Assisted Music Instruction: A Look at the Potential, IBM Laboratory Report 16.164, September 23, 1968.

[3] Ihrke, Walter A., "Programmed Rhythm Training in Automated Music Training," National Society for Programmed Instruction Journal, September 1968.

```
Ready?  iType your name and the date.
Don Andrews
Unit No. 1

Instructions?
yes

Indicate your choice of exercise modes by depressing
ready key after mode name is typed.
System test.
Instant exercise.
Potluck.
Sight singing no. 2.

Please indicate by entering either "just" or "equal" ,
by which method of intonation you wish to be judged.
equal
Register? "h" or "l".
l
If you wish a detailed analysis of your deviation from true pitch
for each note, strike "ready", otherwise enter the criterion
you wish to be used, in terms of the percent deviation, as
"1/2%", "1%", "2%", "4%".
2%

Whenever "ready?" is printed by the typewriter you have these choices-
     1. You may hear the example - press "a"
     2. You may sing the example - press the ready key--An evaluation
of your performance will be printed out for you to see.
     3. You may go directly to the test example - press "t"
     4. You may skip to the next example - press "s"
     5. You may backup to a previous example - press "b"
     6. If you wish to change the criterion by which your performance
is judged,type the new value in before you make your choice.

Exercise # 1. - Set 80

Ready?  t
Exercise # 4. (TEST)

Ready?
Ready?  Sing.
E4      G4      E4      F4#     E4
b       OK      OK      OK      OK
You may try the test exercise once more.

Exercise # 4. (TEST)

Ready?  Sing.
E4      G4      E4      F4#     E4
OK      OK      OK      OK      OK        CONGRATULATIONS.

Exercise # 1. - Set 84

Ready?  t
Exercise # 4. (TEST)

Ready?  Sing.
F#      G       F#      A       F#
OK      OK      OK      OK      OK
Exercise # 1. - Set 88

Ready?  t
Exercise # 4. (TEST)

Ready?  Sing.
F#      G       F#      G#      F#
OK      OK      b       OK      OK
Exercise # 1. - Set 89
```

Figure 3. Example of a Pitch Discriminator Course Printout

The student has a choice of how to proceed and has available a switch control which makes both the background channel and the model channel available. The student can listen to the two channels in combination; the possible choices are:

1. Play what is on the page while hearing the background only.
2. Listen to the background, read the page without playing, and hear only the background music.
3. Listen to both channels, background and model, while playing.
4. The same as (3) without playing.
5. Listen to the model and NOT the background while either playing or not playing.
6. With automatic tape stops at the end of each item, the student may proceed or repeat the previous item, using one of the five options.

This program of automated rhythm training contains items of a wide range of difficulty. A student may enter this program at the appropriate point, and a number of sequences are available that proceed at different rates based on increase of difficulty. In addition to the program being "student-paced" item by item, it can be geared to his ability to proceed.

II. METHODS AND PROCEDURES

A. Overall Methodology

This Phase I feasibility project was organized around accomplishing the following tasks:

Task I	Identification and Analysis of Learning Objectives
Task II	Description of the Present Wichita Keyboard Experience Program
Task III	Determination of Instructional Input-Output Requirements
Task IV	Identification and Costing of Hardware and Software Systems and Components with Potential Application to Keyboard Music Instruction
Task V	Preliminary Design of Alternative System Configurations
Task VI	Selection of an Optimum System; Preliminary Report
Task VII	Feasibility Testing of Design Alternatives
Task VIII	Preparation of Report of Feasibility and Requirements

Procedures followed for Tasks I-VII are described in the remainder of this chapter.

This study was directed toward creating and evaluating conceptual designs for educational programs and systems which might some day -- but which do not yet -- exist. Accordingly, the project's methodology consisted basically of gathering available relevant information from a wide variety of sources, then reasoning from this information by analogy and by extrapolation. This represents only a fraction of what is required in a complete research, development, and application effort. Necessarily omitted in the project were operational trials of working systems, rigorous demonstration of attainment of the goals of music education, and detailed specification of final designs. These must be left to later work. For the present project, the goal was to imaginatively devise educational innovations, to evaluate them as prudently as possible at such an early stage, and to conclude what steps will lead most readily to future widespread actualization and use of the innovations here presented.

B. Task I: Identification and Analysis of Learning Objectives

This task was undertaken to identify specific student behavioral objectives appropriate to the learning of musical concepts through keyboard mediation. The task began with a literature search. Concurrently, personnel of the Music Education Department, Wichita Public Schools, prepared a draft statement of objectives considered appropriate at the elementary-school level.

In general, it was found that the published literature does not treat keyboard experience separately. Nor are the music objectives found in the literature and those furnished by the Wichita public schools expressed in precise behavioral terms. (See Appendixes A and B for statements of objectives furnished by the Wichita public schools and representative statements by other music educators.) There is, in fact, a communication gap between traditional music educators and behavioral technologists.

1. The Communication Gap. Difficulties of communication are seemingly the result of a conflict between the language of new technology and traditional discourse. The character of the language used by traditional music educators is illustrated by the following passage:

> The generally educated person listens with a purpose. He recognizes broad melodic and rhythmic contours of musical compositions...He can concentrate on sounds and the relationship between sounds.[1]

To show the gulf between the above statement and those which a behavioral technologist might develop, consider the following:

> Once an instructor decides to teach his students something ...he must first decide the goals he intends to reach.... When clearly defined goals are lacking, it is impossible to evaluate a course or program efficiently and there is no sound basis for selecting appropriate materials, content or instructional methods....While it is permissible ...to include such (terms) as "understand" and "appreciate" ...the statement is not explicit enough to be useful until

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[1] Ernst, Karl D. and Gary, Charles F. "Music in General Education", Music Educators National Conference, 1965. p.4.

> ...how sampling the "understanding" and "appreciation" is made clear. Until you describe what the learner will be DOING...you have described very little at all.[1]

What seems to be needed are tested objectives which are fully relevant to the integrity of the subject matter and the essential human characteristics (motivation, abilities, and attitudes) of the learner. Perhaps the writing down of such statements is not yet possible. Mager[2] states that some people may believe "many of the things I teach are intangible and cannot be evaluated." He answers with: "...Well, all right...but if you are teaching skills that cannot be evaluated, you are in the awkward position of being unable to demonstrate that you are teaching anything at all." He continues by stating a rationale: "Although it is true that the more important an objective, the more difficult it is to state, you can go a long way toward stating objectives a good deal better than has been the case up to now."

2. Criteria for Behavioral Objectives. The criteria listed below may be applicable to an evaluation of behavioral objectives. Several levels of design and implementation actions are included in these criterion statements, and some selection would be exercised by an instructional program developer in applying them. Also, the list should not be considered as representing all cases or circumstances.

- Are the behavioral objectives stated unambiguously so that teachers, test writers or curriculum developers can use them with clarity?

- Is there empirical evidence that the objectives are in an appropriate or required order?

- Is there empirical evidence that the objectives are grouped into units of appropriate size?

- Are the objectives and units such that there are no gaps or overlapping steps in the ordering of the objectives and units?

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[1] Mager, Robert G. Preparing Instructional Objectives. Fearon Publishers, 1963. p.4, et passim.

[2] Mager, Robert G., op. cit.

- Is there evidence of the validity and reliability of the various diagnostic tests used in the program? (This includes both written tests and various performance tests during classroom experiences.)

- How do the procedures for administering tests and scoring procedures operate?

- Is there evidence that the tests or objectives can provide information for the pupil to use to monitor his own progress?

- Is there evidence that the materials used are appropriate and easily accessible to the pupil or teacher?

- To what degree does individualization take place during the program? Are there alternate routes or types of instructional materials, or arrangements by which the pupils can proceed at variable rates?

- What type of staff training will be required to implement the program?

3. Development of Behavioral Objectives for Keyboard Experience. Efforts were made to apply the foregoing criteria to the development of behavioral objectives for keyboard experience. Statements of objectives furnished by the Wichita public schools were recast in behavioral terms; a subsequent effort was made to categorize those objectives, and relate the statements of Generalized Keyboard Objectives to Wichita's Specific Objectives (Keyboard Experience Program).

The work by SDC was essentially limited to defining terminal behavioral objectives; it was beyond the scope of this feasibility study to fully delineate the objectives down to a subconcept level--such work is properly part of a full-scale Phase II development effort. These terminal behavioral objectives should be considered preliminary and subject to judgmental refinement and testing before they are accepted as a basis for curriculum development.

It is clear that explication of behavioral objectives for keyboard experience, and for music in general, is in an early stage. The complex interrelationships of musical concepts suggest that precise behavioral definitions may be unattainable in some concept areas. But practical working definitions can be developed in a Phase II effort, using the data gathered and originated in Task I as a nucleus. The matrix technique shown in Appendix C may be useful in establishing correlations between general and specific behavioral objectives.

The behavioral objectives for a Keyboard Experience Program should be based on further analysis of the learning task. The learning task should be fully in accord with learner characteristics so that maximum effectiveness will be achieved. Especially important is that the student's own intrinsic motivations and values be considered. Accomplishing the system integration of the influences of teacher-objectives, subject-matter objectives and learner-centered objectives will be a difficult problem.

Basic to the delineation of student motives and values is the suspension (at least temporarily) of adult or subject-matter value judgments. What this means is that what children perceive as important, valuable, and worthy of effort is probably not in full agreement with adult preconceptions. The child's value structure must be taken into account. This does not mean that the student should "dictate" the rules or that an atmosphere of permissiveness or "progressive" techniques be fully acknowledged. The requirement is that the child's innate and scholastic character be acknowledged and that any program or behavioral statements be structured so that the child's energies can be focused without the necessity of persuasion or "orders". If the child's natural curiosity and drive can be channeled into the desired directions, as perceived jointly by learner and teacher, then learning tasks will be easier.

4. Tentative Keyboard Experience Objectives. Objectives for the Wichita Keyboard experience program have been translated into behavioral terms. The resulting 18 statements are listed below and comprise the goal of "teaching the fundamentals to music to third graders."

I. The student will be able to demonstrate his knowledge of classroom procedures.

II. The student will be able to demonstrate his knowledge of keyboard locations and functions (high/low, loud/soft, two/three note groupings).

III. The student will be able to clap hands in correct rhythm to the visual display of a pattern of notes at a moderate meter (mm=60) where the student knows the names of the notes and has had practice with typical groupings of single rhythms.

IV. The student will be able to play from memory any one of a specified set of easy songs.

V. The student will be able to name any note when displayed on a standard treble or base clef.

VI. The student will be able to identify step and half-step intervals on a piano keyboard or visual display when asked.

VII. The student will be able to name and identify the function of any symbol of the typical music symbol set.

VIII. The student will be able to chant the words in correct rhythm to easy songs which have the following meter signatures: $^2/_2$, $^3/_4$, $^4/_4$, and $^6/_8$.

IX. The student will be able to (on command) play all notes on the keyboard with the same name using a hand-over-hand (first right, then left) pattern.

X. The student will be able to play two successive notes to illustrate a 1 to 1, 1 to 2, 1 to 3, 3 to 1, or 2 to 1 duration value when given a visual display.

XI. The student will be able to play the following triad chords in one of these keys: C, F, G, when given a command.

a) Tonic (or I chord)

b) Subdominant (or IV chord)

c) Dominant (or V chord)

XII. The student will be able to "chord" an appropriate accompaniment to his own singing of a specified set of easy songs where the accompaniment comprises simple meters of triads I, IV, V. The student, when given the music, will be able to play a simple melody in ensemble with one other piano.

XIII. The student will be able to play, given the music, either the chord accompaniment or the melody of a specific set of easy songs, with at least one other piano (duet).

XIV. The student will be able to play from memory any one of these major scales (C, F, G) or these natural minor scales (A, D, E) and he will be able to identify the half-steps and whole steps of each scale by naming (e.g., "in C major from E to F is a half-step").

XV. The student will be able to build by playing on the keyboard either a major or natural minor scale on any of these keynotes - C, E, F, G - after hearing any three to six note sequences.

XVI. The student will be able to give as responses the names "flat and sharp" when doing major or minor scale building by playing on the keyboard when asked specifically about the ordinal-number (3rd, 4th, etc.) step of the scale.

XVII. The student will be able to name scale wise and ascending or descending skips in a specified set of easy songs when shown the music.

XVIII. The student will be able to play the 1st, 2nd, or 3rd musical phrase of a single melody of a song from a specified set given the music and the number of the desired phrase.

The foregoing objectives are incomplete, since they do not contain definitions of the conditions of learning or criteria of acceptable performance. Statements about the conditions of learning, such as materials, procedures, and learner characteristics, should be obtained from a thorough study involving students, teachers, and instructional materials. The criteria of acceptable performance, as well, need to be decided on the basis of a study of actual classroom circumstances. It is not enough for an educational analyst to presume the criteria--they should be stated by the relevant persons, perhaps including students. In this way some of the pitfalls of traditional educational practices may be avoided. The student and the teacher are in a good position to say, relative to their own experiences, what is acceptable and what are the criteria of performance in achieving the behavioral objectives.

5. A Music Concepts Model for Keyboard Experience Objectives. A separate contribution was made by Dr. Raynold Allvin, consultant to the project. While his contribution is not couched in specific behavioral terms, the integrated conceptual approach he follows (Tables 1 through 4) constitutes a useful model for a Phase II effort. Table 1 identifies nine areas Allvin believes should be covered by the end of the third grade. Table 2 identifies the

Concept objectives for Area II (Melody). These objectives, in turn, are divided into two experience groupings in Tables 3 and 4--those that can be taught or reinforced through keyboard experience and those which are mainly non-keyboard oriented. Both sets of experiences can be coupled in an integrated music program to develop the concept objectives. Allvin's thesis is that, if the keyboard learning is properly structured, the desired conceptual experiences can be gained concurrently with the acquisition of basic keyboard skills; that is, the instructional plan for developing basic keyboard skills should be superimposed on the plan for developing conceptual experiences. There is no presumption on Allvin's part that every music educator would agree with all details of this outline, but there is a strong conviction that most music educators would agree that the concept objectives for melody are correct.

Table 1. Concept Objective Areas

I. Rhythm
    A. Kinds of Movement (tempo, meter)
    B. Rhythmic Motives
    C. Accent groups
II. Melody
III. Melodic Motives
IV. Intervals
V. Pitch Notation
VI. Chords
VII. Harmony
VIII. Tone Color and Texture
IX. Form and Style

Table 2. Concept Objectives for Melody

By the end of the third grade, these musical concepts should have been developed through various experiences.

1. Melodies move by rising, falling or staying on one level.
2. Melodies move by scale steps (conjunct), by larger steps (disjunct), or by repeating notes.
3. Melodies may flow continuously from beginning to end or may be divided into small segments or motives.
4. Certain tones seem to be restful. Other tones tend to lead to the restful ones.
5. Melodies may be divided into two or more large parts called phrases.
6. Some melodies can be made of only five tones (pentatonic scale).
7. Some melodies sound dark or sad, others bright or happy (objective related to a similar one in harmony).

Table 3. Keyboard Experiences Helpful in Developing Concept Objectives for Melody

This Keyboard Experience Develops------	This Concept (See Table 2)
Melodies of each sort are demonstrated visually on the keyboard.	1,2,3
Student learns to play by rote an example of each sort of melody.	1,2,3
Student improvises melodies incorporating each type.	1,2,3
Student reads from notation, during course of skill instruction, examples of each type of melody.	1,2,3

Table 3, Continued

This Keyboard Experience Develops------	This Concept (See Table 2)
Higher notes on printed music are created by playing notes farther to the right.	1,2,3
Motives are made clear on the keyboard by using very brief silences between the beginning of one and the end of the last. Frequently accomplished by a slight lifting of fingers from the keyboard. Converse activity should be provided for connecting notes and melodies.	3
Within scales, find notes which are restful or not restful. Generalize from the experience which degrees of the scale are always restful or not restful and which tend to move to which.	4
Determine, by experimentation, that there is practically no difference of feeling of rest or non-rest within the 5-tone scale.	6
Since tones are nearly equal in importance, composers and performers must show where they want the listener to consider the melody as finished. (Related to concepts of dynamics, tempo, and meter.)	6
Play Melodies in both major and minor.	7
Construct major and minor melodies.	7

Table 4. Non-Keyboard Experiences Indispensable for Developing Concept Objectives for Melody

This Non-Keyboard Experience Develops---	This Concept (See Table 2)
Listen and identify (by overt response) each variety. That is, choose, from a given set of presented musical examples, those which best fit the categories.	1,2
View written music of each kind, noting: (1) Rise in written notation produces a higher pitch. (2) Skips are represented by greater distance between notes. (3) Scale steps use consecutive lines and spaces.	1,2
View examples showing clearly articulated motives and continuous phrases, as compared to the audio of the same.	3
Melodies have a half-cadence or partial relaxation somewhere along the way. Listen and identify these pauses.	5
Melodies built on pentatonic scales may begin and end anywhere. Experience the difference between pentatonic and diatonic.	6
Identify, by overt response, major and minor scales, chords, and melodies.	7

C. Task II: Description and Analysis of the Present Wichita Keyboard Experience Program

The purpose of Task II was to describe the major student-teacher-keyboard interfaces in the Wichita Keyboard experience program. To capture the actual classroom situation as closely as possible, between 30 and 40 hours were spent in the mobile vans to listen and take notes. Ideally, this time would have been spread over an entire school year; because of project timing and scheduling, the time spent covered only the latter part of the school year. However, this was not considered prejudicial to the project because material covered near the end of the school year included the basics covered at the start of the school year.

In addition to classroom observations, interviews were conducted with the keyboard experience teachers, classroom teachers, elementary-school principals, and administrative personnel. All materials used in the program were also acquired for study.

The program is taught by two keyboard experience teachers. Classes are conducted in two mobile vans. Each van houses 22-23 Wurlitzer electronic pianos connected via cabling. The teacher's piano console allows the teacher to communicate with individuals or groups of students. The console additionally permits students to hear only their own piano or to play in ensemble. Each student piano has a three-position switch by means of which a student can listen to his own playing through a headset, a speaker, or in ensemble through his headset. A student can control the audio volume of his own piano, but not the audio volume of the teacher's console and microphone.

The program is operated along traditional classroom lines; that is, it is a lock-step system in which opportunities for individualized instruction are minimal. Variations in lesson presentation occur principally for three reasons: (1) teacher style; (2) efforts to relieve teacher tedium by varying the content and scheduling of content from class to class; and (3) class size--classes range in size from 9 to 22 students and it is possible to proceed at a faster pace and to provide more individual attention in the smaller classes. However, since the average class size was 17 students during the 1968-1969 school year (about 1800 students from 11 different schools), the amount of individual attention the teachers can give students in any 30-minute session is severely limited. This is a source of frustration for the teachers, who are skilled and dedicated.

Music texts, Vu-graph displays, wall charts, and blackboards are the principal media employed in instruction; these are complemented by verbal instructions and demonstrations on the teacher's console. The basic text used is "Keys, Fingers, and Notes to Music," especially prepared for the program by Mr. John Schneider, of the Wichita schools, the first to teach the program. Other music texts used--especially for classes in their second and third years in the program--are Robert Pace's "Music in the Classroom" and Sally Monsoor's "Play". Indicative of the coverage in the course is the check sheet used by the teachers (Figure 4).

It was observed that tape recorders are rarely used, despite the fact that two audio input channels are available on the teacher's console for presenting instructional material (Wurlitzer's later laboratory provided four audio input channels). Output jacks are available on the student pianos for recording and monitoring; these, too, are rarely used. The teachers periodically monitor the playing of individual students through switches located on the teacher's communication center.

No official grades are given in the keyboard classes. The school administration's position is that the students in the program should not be required to attain any preset level of proficiency or be graded. However, certificates of participation and unofficial grades are given to each student at the end of the school year.

The most graphic description of "what actually goes on in the keyboard experience classroom" in a typical day is given in notes compiled by SDC personnel while acting as observers. Representative samples of those notes are included as Appendix D. At that time (spring of 1969), classes were conducted once a week, the duration of each class session being 30 minutes. The teachers in the program felt that the interval between class sessions was too long and adversely affected the students' ability to retain previously presented material. During the present school year, some classes are being held twice a week to overcome this problem and increase the effectiveness of the program.

The program is now in its fifth year. The only quantitative data available concerning its effectiveness are test results compiled during the first three years of operation. The "Wood-Boardman Test of Musical Discrimination for the Primary Grades" was used to measure progress in musical discrimination and the ability to identify the organization of musical sounds. This test was divided into six subtests, and the Music Education Department of the Wichita Public Schools added a seventh subtest to measure the students' knowledge of notation. Since results consistently showed a significant difference between keyboard experience classes and control groups, favoring the former, further testing was considered

SCHOOL__________________ DAY______ GRADE______ HOUR______ to______

Teacher(s)__________________

Keyboards ______
Black note groups ______
Up-down ______
High-low ______
Finger Numbers ______
Repeated Noted ______
A B Cs ______
Ds______ Cs______
Es______ Gs______
As______ Fs______
Bs______
Scales (Discovery) ______
Scales (Analysis) ______
Scales (Construct) ______
C______ F______
C______ Bb______
D______ Eb______
A______ Ab______
E______
Rhythm:
Long-short-long ______
Even-uneven ______
Two-threes ______

Harmony:
Major Sound ______
Minor Sound ______
Major Chords
I Chord ______
V_7 Chord ______
IV Chord ______
Need Chord Change ______

Phrases (Form):
Like-different
AB ______
ABA ______
Theme & Variations ______

Echo Playing ______

Notation:
Grand Staff ______
Treble Clef ______
Bass Clef ______
Half-Qtr. ______
Whole-eighth ______
Whole rest ______
Half rest ______
Quarter rest ______
Eights rest ______
Accidentals:
Sharps ______
Flats ______
Naturals ______
Repeat Sign ______
Fermata ______
Instruments:

Rote Pieces:
Hot Cross Buns ______
Love Somebody ______
Go Tell Aunt Rhodie______
Merrily ______
Oats, Peas, Beans ______
Wind Blew Last ______
Other:

Worksheets:
101 ______ 102 ______
103 ______ 104 ______
105 ______ 106 ______

D1	B1
D2	B2
D3	B3
D4	B4
D5	B5
D6	B6
C1	A1
C2	A2
C3	A3
C4	A4
C5	A5
C6	A6

Figure 4. Wichita Keyboard Experience Program
Seating Chart-Check Sheet

unnecessary. Subjective data gathered by the school administration from classroom teachers, school principals, and parents further substantiated the value of the program.

D. Task III: Determination of Instructional Input-Output Requirements

This task was found to be efficiently subsumed into Tasks I, II, and V.

E. Task IV: Identification and Costing of Hardware and Software Systems and Components with Potential Application to Keyboard Music Instruction

Task IV was undertaken as a preliminary step to the development of alternative concepts for computerizing keyboard instruction. Four areas were studied: (1) computer hardware and related equipment, (2) computer software, (3) audio-visual equipment (non-computer), and (4) keyboard equipment.

1. Computer and Computer-Related Equipment. The computer-related equipment relevant to keyboard music instruction can be divided into three classes: keyboard to computer interface equipment, data processing equipment, and student terminal displays. The classes are not independent; the nature of the interface equipment, for example, will affect the nature of the data processing required. The equipment required is also a function of the instructional techniques to be automated. This section describes some available alternatives.

a. Keyboard to Computer Interface Equipment. First, the electronic organ may be easier than an electronic piano to interface to a computer. Many of the necessary components--specifically, switches and electronic tone generators--are already available in the electronic organ. When the mechanical tone generation characteristic of most electronic pianos is considered, the interface equipment must take care of:

- Generation of keyboard information in computer-usable form.

- Generation of tones if the computer is required to "play" the piano.

All interface equipment must be specifically designed and built for these applications, as commercially available equipment has not been discovered.

(1) Piano Input-Output

(a) Input for the Computer. The basic information needed for computer processing is the time sequence of specific notes played. This sequence allows most of the information about the music performed (such as notes, tempo, rhythm, etc.) to be calculated. It does not provide any information about keyboard technique such as fingering.

Two methods for producing information on time sequences and intensities of notes are to:

- Analyze the audio output of the electronic piano.
- Instrument the keyboard and obtain a time sequence of key-depressions.

If the first method is to be used, then a spectral analysis of the piano output as heard by the student is required. (Schemes such as that used by IBM in their "pitch-extractor" training system cannot be used readily because a piano can play more than one note simultaneously.) The problem with a spectral analysis (i.e., an energy versus frequency distribution) is that a single note contributes energy at more than one frequency. Thus, there is no simple relationship between the spectrum and the notes that have been played. Another problem is that such an analysis would be difficult. Analog equipment for each piano would probably be prohibitively expensive, and generating the spectrum in a digital computer by fast Fourier transform would tend to be slow and require large amounts of computer memory. For these reasons, analysis of the audio output is deemed not practical.

Certain modification of the piano allows an alternative method, using audio output. If the notes generated by the vibrating reeds, as in the Wurlitzer piano, are mixed in the metal bar behind the reeds and if this bar is separated into segments for each reed, then single output lines can be provided for each reed. These lines can be sampled. Energy on the line indicates the note played, and the amount of energy is a function of the intensity of the note. In addition to mechanical modifications, a mixing amplifier (costing \$10-\$20/piano) would be needed to mix all notes together for the single output. Connections would be made to the separate output lines for the interface and will be described below.

The alternative to using the audio output would be to instrument the keyboard. The easiest way is with switches, although magnetic or photo-optical techniques might prove superior when the details of the actual design are considered. Two switches per key would be required to obtain note intensity. Actually, note intensity is not measured directly; the measurement would be of key velocity, which is roughly related to the intensity of the note. The switches can be arranged so that they close at different points in the key travel. Either switch could be used to indicate that the key had been depressed. The time difference between switch closings is an indicator of key velocity.

(b) Output from the Computer. Direct piano output from the computer can be accomplished by solenoid drivers on the piano keys or action. With this, the computer could "play" the piano directly. Intensity control would be difficult, and the effect would be similar to a player piano. The solenoids would move the keys, and the student could follow the key action. However, such a system would be difficult to integrate into the current electronic piano, would be expensive, and might be difficult to maintain.

Alternatives include use of audio-tape playback and a computer-controlled tone generator. Audio tape is restricted to prerecorded sequences. Computer-controlled tone generators provide variability in sequences, tempo, etc., but can be expensive. Tone generators would constitute an electronic organ system which could be used for student instruments (substituting for the piano) as well as for computer-controlled playback.

(2) Interface to the Computer. This section discusses some possible ways of connecting the piano to the computer. The intent is to educe the interaction between interface and processing equipment.

(a) Input to the Computer. The problem in the interface is the preservation of timing information. Unless this information is generated and retained in keyboard logic, the interface must be designed so that the computer can quickly respond to changes in keyboard state soon after they occur. The amount of time that can safely elapse depends on the method used to get information from the piano and whether note intensity information is needed.

Assuming 64 keys per keyboard, the basic keyboard unit will provide 64 or 128 lines of analog or digital information, depending on the method used. There are a number of possible ways of providing this information to the computer. One is a polling system whereby a multiplexer is provided to allow the computer to individually address each line. The computer then repeatedly checks each line for changes in state. This approach is one extreme in that it minimizes interface equipment at the expense of computer time. With 2,048 or 4,096 lines (32 pianos, 64 keys/piano), it is questionable that a state change would be sensed before timing information is lost (especially key velocity timing if 2 keyboard switches are used). Most of the available computer time would be taken in the polling operation, leaving little for anything else.

The other extreme is a piano keyboard logical unit which encodes and accumulates key and timing information and interrupts the computer to transmit this information when a reasonable amount has been stored. This requires extensive logic but minimizes computer time.

A solution probably lies somewhere between these two extremes, using interrupts and polling. For instance, a keyboard logic unit could interrupt the computer when a change in state (key depression or key release) occurred. The central computer could then poll the lines of the interrupting piano for changes in state. This allows quick reaction to state changes while reducing the amount of unnecessary polling.

With these interface techniques, a comparison between the analog and digital methods of obtaining keyboard information can be performed. With a pure polling system, the analog system may be cheaper because it provides inherent storage of intensity information.

(b) Output to the Piano. Techniques to enable the computer to play the piano are inverses of those used to obtain information. A polling system would require the computer to update the state of each line (key depressed or released) each polling cycle. The interrupt and polling system will provide each piano with a clock, which could be set to interrupt the computer at the maximum note rate. At each interrupt, the central processor scans its output music information to determine which, if any, keys need to be actuated. Since each key is either actuated by the student or by the computer, some of the logic could be shared between the input and output modes.

b. Visual Displays. Displays may be needed at the student terminal to provide instructions and instructional material. There are essentially two types of display devices available: those which can present prestored material as selected by the computer, and those which can present material generated by the computer. Both types may be useful in a student display terminal.

The most common display for prestored materials is the so-called random-access slide or filmstrip projector. These allow any one of 80-100 images to be projected on a screen, with an access time to an image of a few seconds maximum. If more images are needed, a number of these devices can be coupled together. The cost of a single projector, exclusive of computer interface (which would vary among computers) varies from $800-$1,200. These prices cannot be expected to change much unless a larger market develops. Further developments could lead to a device storing 256 images at a cost of $400-$500. The University of Illinois has developed a prototype random-access slide selector of this type which is pneumatically driven and has a removable plate of film.

A number of alternatives (existing or in development) are available for display of computer-generated material. Those available now are based on cathode ray tube (CRT) technology. The potential exists for the replacement of the CRT by new forms of display devices.

CRT's come in two varieties--storage and non-storage. The non-storage CRT, the most common type, requires that the image be continually refreshed to maintain a viewable display. This requires storage for the image, either in the driving computer or in the display itself. Non-storage CRT's are used in graphic displays, which provide a full character and line-drawing capability, and alphanumeric displays which provide only alphanumeric text. Graphic display costs start at about $50,000 and can go considerably higher. Alphanumeric displays, with keyboard and light pen, cost about $4,000. This cost is not likely to drop appreciably in the next few years. In the past few years, many new alphanumeric displays have been introduced with no real decrease in minimum cost.

The storage CRT is a recent development which eliminates the need to refresh the image and thus eliminates the memory requirement. Image contrast is not as good as the non-storage CRT. Light pens are difficult to use. Terminals utilizing these CRT's are now available and cost less than $9,000, including keyboard and standard interface. They have both graphic and alphanumeric capability. Some lowering of this price can be expected in the next few years, as new competitors introduce displays, but not much. There is, and probably will continue to be, only one supplier of the CRT and associated analog drive electronics. Storage CRT displays can be expected to have an operating cost of 5¢ to 25¢ per hour to amortize the replacement cost of the CRT.

Potential alternatives for the CRT are many: electroluminescent panels, injection-laser matrices, gas-discharge panels, liquid-crystal systems, thermo-chromic-element matrices, and magnetic-field-polarization-element matrices. The most publicized (and possibly the most promising) is the gas discharge, or plasma panel, developed at the University of Illinois. One current prototype price for a 4 X 4 inch display panel is $1,500. In the future, it should be possible to get an 8 X 8 inch display panel for about $3,000. (These cost estimates may change markedly as development proceeds.)

One other possibility for a student terminal that should be mentioned is the non-impact printer. These are small, quiet printers operating at 200-300 characters/second. These devices cost $2,000 to $5,000 each. One problem for many is that they require special paper at 1¢ to 5¢ per 8-1/2 X 11 inch page. The advantage is that they produce a hard copy.

As a present estimate, a satisfactory student terminal including film display, computer display, and input keyboard would cost $10,000-$11,000 each in small quantities. In the next 5 years, this will probably be reduced to $5,000-$6,000.

c. Random-Access Audio Devices. While we were able to obtain only fragmentary information on digitized audio-storage hardware, the costs indicated appear to make this alternative prohibitively expensive. This capability has been introduced in the experimental CAI system headed by Dr. Patrick Suppes at Stanford University. The Stanford system seems to solve a selection problem at the expense of storage. It requires 36,000 bits for each second of audio output (probably an average of 20,000 bits per word). Two kinds of storage are required: each word must be permanently stored on disk (or other mass storage), and a message prepared for output must be stored in core memory. Thus, a 5-second message for output (6-12 words) requires 180,000 bits of core memory when it is to be generated. This is a highly inefficient encoding system because specification of one word out of 5,000 (storage capability of the Stanford system) would require only 13 bits. However, a computer with disk storage is well suited to random selection of items from a large list. With music, this selection problem is lessened with only 32 notes; even so, the Stanford system does not appear to be economically feasible. To generate music encodings of one second (or so), each of the 32 notes could be stored, and sequences of notes could be generated by the computer. (It may be extremely difficult to generate chords, depending on the form of the encoding). This method would require considerable core storage for buffers. With 32 pianos, an average output length of 10 seconds, and an average of 10 percent of the students receiving output at any one time, core-storage requirements would be over 1,000,000 bits (at a cost of $.05 per bit). This is a lot of storage for the output function alone. Adding up the cost of storage and the cost of digital-to-analog converters and other special equipment needed (e.g., multiplexers), it seems that the audio output can be much more easily and cheaply generated with a system containing tone generators and switches, or a digitally addressed audio storage (in analog form) device.

The IBM 1500 Instructional System uses an audio response unit which can store up to 2 hours and 40 minutes of separately addressable audio messages. The audio messages can vary in length from 1/2 second to about 4.3 minutes. The unit operates at a 1-7/8" playback speed and has a slew (fast forward or reverse) rate of 18 inches per second. No figures are available on average access times, although it can be inferred from the slew rate that it is several seconds. One of these units is required at each student station; the estimated but unconfirmed price of the unit is $4,000-$5,000. Additional equipment is required to prepare and prerecord audio messages on the unit.

Another random-access audio device is under development for the PLATO system at the University of Illinois. No details are available at present on its status, probable cost, access time, or storage capacity.

d. Central Processing Units. The processor configuration will most probably include a "mini-computer". These computers are characterized by relatively small word size (8, 12, 16 or 24 bits), fast core memory cycles (0.6 to 2.5 microseconds), and limited instruction sets. They have a powerful but simple input/output system which lends itself to process control, or in this case, to keyboard instrument control. Time-sharing systems have already been programmed for them. Typical machines in this class are the IBM 1130, the Honeywell DDP-516, and the DEC PDP-15. Depending on the instructional strategies used, the processor configuration might be:

(1) A single mini-computer with disc and/or tape storage for instructional material.

(2) Two or more mini-computers. One computer would handle keyboard and other input/output, the other(s) would control the instructional processes.

(3) One mini-computer and one large data-processing machine. The mini-computer would handle the keyboard and the student displays. The large data-processing machine could be time-shared to handle many keyboard instruction units and/or instructional or data processing tasks.

If the first alternative is viable, a typical system might include:

(1) A central processor with 12-16,000 words of 16-bit core memory. This memory would be needed to store the executive and interrupt service routines along with a reasonable amount of instructional material for each terminal.

(2) Disk storage of instructional material, since not all material could be in core memory simultaneously.

(3) IBM-compatible magnetic tape unit for loading the disk and storing student data for later off-line processing.

The approximate costs of these items would be $45,000 for the computer, $20,000 for the disk storage, and $20,000 for the tape unit, for a total of $85,000.

In the next few years, we can expect cost improvements in logic design, logic components, and memory components, resulting in perhaps a 25% price reduction for a user of these items. However, no cost improvements in electromechanical devices (tape, disk) are likely. With a 25% logic and memory price reduction, the mini-computer system price would drop to $70,000. More dramatic cost reductions are likely to occur by 1980.

The costs of a large-scale computer system typically range from $1,000,000 to over $2,000,000 at the present time.

2. Computer-Assisted Instruction (CAI) Software. Two types of software effort must be considered when discussing CAI--language development and instructional programming. A CAI language provides the communication link between the lesson designer (instructor or programmer) or the lesson user (student) and the computer. Instructional programming uses a CAI language to prepare lesson material for presentation to the student.

It is extremely difficult to isolate and determine, with any degree of accuracy, the costs involved in the development, installation, and on-going implementation of CAI languages and course material. This is partly because CAI is in its infancy and the vast majority of work accomplished to date has been in the research and development stages. In this environment, specific costs are not always easily identifiable; when they are known, they are usually not published due to the high amounts involved.

Some computer manufacturers provide CAI software systems with the purchase or rental of the computer equipment. These include IBM with its Coursewriter languages and RCA with its instructional languages. These language systems cannot be procured separately but are supplied as part of the support package provided with the lease or purchase of the computer equipment.

Overall estimates of CAI costs (hardware and software) vary considerably due to the many variables which can affect the costs, e.g., amount of time computer operates, type of CAI logic used (drill and practice, Socratic, etc.), or communication required, to mention just a few. Suppes[1] states that supplemental drill and practice programs in the elementary school would cost about $50 per student per year for the total CAI program, about twice the amount he considers desirable. In the report of the New York State Conference on computer uses[2], it is estimated that the cost per pupil per hour would be $2.27 for drill and practice programs and $7.53 for other tutorial programs. These estimates assume a student population of 10,000, with one hour per day being spent on CAI by each student. A Mitre Corporation study[3] estimates that per-student-terminal-hour costs range between $.10 and $.37 per hour for a 10,000 terminal time-shared computer-controlled ETV system.

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[1] Suppes, Patrick, "How Far Have We Come? What's Just Ahead?", Nation's Schools, October 1968.

[2] Gould, Thomas, ed., New York State Conference on Instructional Uses of the Computer, Draft of Final Report, the University of the State of New York, Albany, New York, 1968.

[3] Nuthmann, C. F., On the Feasibility of a 10,000 Terminal Time Shared Interactive Computer Controlled Educational Television (TICCET) System, The Mitre Corporation, Washington, D. C., May 1969.

There are numerous CAI courses that have been and are presently being developed through out the country. Usually each CAI center and commercial producer of CAI programs provides descriptions of their available programs. The ENTELEK Computer-Assisted Instruction Guide[1] is one source which describes many CAI programs which are actually operational and available throughout the country at a variety of locations. CAI courses have been developed for almost every subject matter field and all age levels. Although some CAI courses in the field of music have been developed, they are usually related to basic music concepts (non-instrument oriented) or to music theory. Figure 5 provides a list of some CAI programs in music.

There are many languages used for CAI. Zinn[2] states that more than 30 languages and dialects have been developed for writing instructional programs. Some of the more well known include BASIC, Coursewriter, Eliza, PLANIT, PLATO, and MENTOR. These variously emphasize tutorial procedures (sequences of lecture or textbook material), drill and practice (question and answer sets), problem solving (use of computer to resolve mathematical or scientific problems, sometimes including a diagnostic capability), or simulations and games (setting up situations which through use will teach a skill or test a hypothesis). For further discussion, see the ENTELEK publication on Computer Assisted Instruction[3] and Frye's article in the September 1968 issue of Datamation[4]. Zinn's work,when completed, will provide the most comprehensive study.

The development of a new CAI language should not be necessary each time another institution wants to establish a CAI program. Use of existing CAI languages (as well as course materials, if appropriate)

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[1] ENTELEK, Inc., Computer-Assisted Instruction Guide, Newburyport, Massachusetts, 1968.

[2] Zinn, Karl L., Draft of "A Comparative Study of Languages for Programming Interactive Use of Computers in Instruction," Center for Research on Learning and Teaching, University of Michigan, Ann Arbor, Michigan, November 25, 1968.

[3] Hickey, Albert E., Ed., Computer-Assisted Instruction: A Survey of the Literature, Third Edition, ENTELEK, Inc., Newburyport, Massachusetts, October 1969.

[4] Frye, Charles H., "CAI Languages: Capabilities and Applications", Datamation, September 1969, pp. 34-37.

School	Name of Course	Brief Description of Course	Computer Used	Language Used
U. of Texas	MUSPITCH	Basic concepts in music and music sound	IBM 1440	Coursewriter I
Penn State U.	CLARINET	Articulation and phrasing of the clarinet	IBM 1410 or 1710	Coursewriter
State U. of N.Y. Brockport	Unknown	Music theory	IBM 1400	Unknown
"	Unknown	Music discrimination	IBM 1130	Unknown
"	Play and publish	Use of computer to compose a piece of music followed by the use of a plotter to publish what was written	Unknown	Unknown
State U. of N.Y. Binghamton	Unknown	Music theory	Unknown	Coursewriter

Figure 5. CAI Programs In Music

should be accomplished whenever possible. Kopstein and Seidel recognize this in their study[1]. They consider two types of requirements--first, the development and/or revision of languages and second, the installation of the language in a specific computer complex. They estimate that it will cost about $4,000 per month (based on an assumption that 10 CAI facilities will share the developmental effort and costs) for both types of requirements. Putting this in an incremental cost per student-hour frame of reference, the costs would range from $.02 per student-hour (for a 448 terminal system used 18 hours a day, 24 days a month) to $1.52 (for a 20 terminal system used 6 hours a day, 22 days a month). Bitzer and Skaperdas[1] in their design of a 4,000-terminal system at the University of Illinois estimate that software, exclusive of lesson material, will cost $.04 per student contact hour.

System Development Corporation developed a CAI language called PLANIT (Programming Language for Interactive Teaching) for an initial cost of $180,000. This also included some costs for the development of several hours of lesson material for statistics and programming courses. The present version of PLANIT uses the SDC Q-32 time-sharing system. Recently, the National Science Foundation awarded SDC a $433,000 contract for further development of PLANIT into a transferable, machine-independent language which will operate on small, medium, and large computers. Only a small amount of additional programming is estimated to be required in order to install it on a particular computer once this project is completed.

The costs for developing course material for use in CAI vary greatly. Bitzer and Skaperdas[3] state that reported costs for producing similar lesson material have ranged over a factor of 10. They attribute this range to differences in author languages. The report on a New York State Conference on CAI[4] states that curriculum preparation ranges between 40 to 200 hours for each hour of student time at a terminal.

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[1] Kopstein, Felix F. and Seidel, Robert J., Computer-Assisted Instruction Versus Traditionally Administered Instruction: Economics, Human Resources Research Office, the George Washington University, Alexandria, Virginia, April 1967.

[2] Bitzer, D. and Skaperdas, D., The Design of an Economically Viable Large-Scale Computer Based Education System, University of Illinois, Urbana, Illinois, February 1969.

[3] Bitzer, op. cit.

[4] Gould, op. cit.

With variances such as these, it is extremely difficult to estimate instructional costs. However, Kopstein and Seidel[1] estimate that incremental instructional programming costs range from $.002 per student hour (for a 448 student terminal system, 18 hours a day, 24 days a month) to $.18 (20 students, 6 hours a day, 22 days a month). Bitzer and Skaperdas[2] equate the costs for preparing CAI course materials to those of writing a textbook, that is approximately $.03 per student hour, based on 40 hours of classroom instruction per week.

3. Audio-Visual Equipment (Non-computer). Information in this area is so widely available that no detailed coverage is considered necessary in this report. The most significant advances have been made in cassette players and player-recorders, which range in price from $12 to over $200. Audio quality is surprisingly high. A large number of synchronized audio-visual teaching machines are on the market, at prices ranging from $25 to $800; these commonly employ either cassette tapes or platter records for the audio, and film strips or 35 mm slides for visuals.

4. Keyboard Instruction Equipment. Two types of commercially available keyboard instruction equipment were surveyed: electronic pianos and electronic organs.

In electronic pianos, tones are generated by conventional piano mechanical keying action. When a key is depressed, a piano hammer strikes a free-mounted tone generator, typically a fixed-pitch reed or tuning fork, causing it to vibrate at its designed frequency. A separate tone generator is used to generate each note on the keyboard. A damper stops the vibration when the key is released. This mechanical vibration is converted to an electronic audio signal by a capacitive-type pickup and amplified before input to headsets and speakers. The tone produced by this action decays in volume after the key is depressed and stops when the key is released[3]. Of importance is the fact that one pickup (containing two pickup plates extending the length of the piano's entire reed assembly) is used for all tones--separate pickups are not used in the equipment surveyed.

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[1] Kopstein and Seidel, op. cit.

[2] Bitzer, op. cit.

[3] A foot pedal can be depressed to sustain the tone even though the key is released. The volume still gradually decays.

Organs, on the other hand, may use purely electronic tone generators. These tone generators are conventional audio-frequency oscillators with associated frequency-divider circuits. A separate output circuit is provided for each note on the keyboard. The tone generators are continuously running, but the output circuits to headsets and speakers are closed only when the associated keys are depressed. The tones produced by this method are sustained in volume, rather than decaying, as long as the key is depressed. When the key is released, the tone is cut off.

A representative configuration of each type is described below--the Wurlitzer Music Laboratory (piano action) and the Conn Music Learning Center (organ action).

a. Wurlitzer Music Laboratory

(1) Description. The equipment described here is of later design than that being used in the Wichita Public Schools. The configuration consists of one Model 207 Instructor piano and up to 24 Model 206 student pianos arranged in 4 groups of up to 6 pianos each. Complete operating and installation instructions, and schematics, are readily available. This description is limited to explaining the significant differences between the new equipment and that purchased in 1966 by the Wichita Public Schools for use in their mobile van program.

The tone-generation system is the same as in the earlier equipment. But the electronic communication center is an integral part of the instructor's console rather than being a separately housed unit. All controls for the communication center are mounted above the keyboard on the front of the console. Two-way audio-keyboard communication is provided--students and teachers are provided with combination headset-microphones; in the earlier equipment, only the instructor was equipped with a microphone for one-way voice communication to the students. Four audio-aid channels for tape recorders or phonograph players are provided, versus two in the earlier equipment. A six-position switch is included in the base of the student pianos to set and change (if desired) the piano number in a group from 1 through 6 to link each piano to the proper communication switch on the communication center control panel; in the early equipment, this number designation was fixed at the factory. Closed-circuit instruction of from two to five students within a group can be conducted for the playing of duets, trios, etc. In this operating mode, audio-keyboard communication is provided between the selected students and the instructor, and the remaining students can practice undisturbed; this mode of operation was not previously available. Also, in the earlier equipment, only one group could play in ensemble. In the new equipment, the control circuitry permits the instructor to "mix" two or more groups for ensemble playing. In this operating mode, audio-keyboard communication is provided between the students in the selected groups and the instructor. Students in the other groups can practice undisturbed.

(2) Specifications. Refer to Figure 6.

(3) Costs. A breakdown of costs for the Wurlitzer Music Laboratory follows:

1 - Model 207 Instructor Console Piano with built-in Electronic Communication Center, Instructor Headset with microphone, Model 8308 Master Cable, five Connector Cables for one group of six Student Pianos, and Bench

6 - Model 206 Console Pianos with Benches, deluxe Headsets with microphones, built-in switches, and Cable Connections

TOTAL. $4455.00

Each additional group of six Model 206 Student Console Pianos with Benches and Cable Assembly Model 8309

TOTAL. $3590.00

COMPONENT COSTS

Model 207 Instructor Piano, per above.	$945.00
Model 206 Student Piano, per above	$565.00
Bench.	$ 20.00
Cabling for each additional group of six or less student pianos	$ 80.00

Dimensions	32-7/8" high; 40" wide; 18-9/16" deep.
Weight	Approximately 130 pounds with bench.
Musical range	64 notes, A-13 (55.000 cps) to C-76 (2093.005 cps).
Action	Grand-piano type; touch control of stroke dynamics, action weight, ring time, and let-off similar to conventional piano.
Tone generators	Sandvik steel reeds precision tuned and aged to maintain pitch constancy.
Speakers	Model 206: two 4" x 8" oval speakers. Model 207: one 6" x 9" oval speaker.
Power requirements	40 watts; operates from 117-volt, 50/60 cycle a.c. 3-wire center grounded a.c. cord available. All student pianos operate from a single a.c. source (no special conduit or wiring required).
Amplifier	Solid state, using silicon transistors and diodes.
Pedal	Sustaining pedal lifts dampers, permits tone to sustain as in conventional piano.
Headset with microphone	High-fidelity cushioned earphones with microphone.

Provisions for:

a. Closed-circuit individual instruction for 1-24 students.
b. Closed-circuit group instruction for two or more students within a selected group.
c. Closed-circuit channels to accommodate four groups of 6 students each, which permits four different group instruction modes simultaneously.
d. A selected group or groups to engage in closed-circuit ensemble rehearsal or groups to be mixed for multi-ensemble rehearsal--with facilities for instruction or monitoring the group(s) or individual student(s) within the group(s).
e. Students in selected group(s) to audit recorded tape and/or phonograph records through 4 separate audio-aid channels.
f. Instructor to speak and override all student activity in closed circuit with a Group Call switch.
g. Electronic metronome (optional).

Figure 6. Wurlitzer Models 206 and 207 Specifications

b. Conn Music Learning System[*]

(1) Description. The system consists of one instructor console and up to 24 student consoles, divided into four groups of up to six stations each. The organ concept with sustained tone is used, which provides exact control of tone volume and duration in depressing and releasing keys; the tone remains constant as long as the key is depressed. Tones are electronically generated in the instructor's console only, using 12 tone-generator circuits, one for each of the top 12 notes on the 44-note keyboard. Each circuit consists of a Hartley oscillator and a flip-flop multivibrator frequency-divider chain. The output of each flip-flop is exactly half the frequency of the input frequency. Notes F5 through C6 have three flip-flop dividers and notes C#5 through E5 have two dividers, giving a total of 44 notes ranging from F2 through C6. Thus, there is a separate output circuit for each tone. Student consoles contain no tone generators and hence cannot be played independently.

(2) Specifications

Teacher's Console:

Dimensions: 25" x 9" x 38-1/2"

Weight: 209 lbs.

Electrical Power: Standard 110-volt outlet

Circuitry: Solid state

Student Console:

Dimensions: 32" x 10" x 5-1/2"

Weight: 22 lbs.

(3) Costs

Teacher's console with 6 student stations.	$3800

Price includes teacher's console, student stations, and all accessories. Additional student stations are $300 each.

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[*] This system is no longer available.

F. Task V: Preliminary Design of Alternative System Configurations

Three alternative design configurations[*] were developed, in preliminary design form, for computer-based keyboard instruction at the elementary-school level. A description of each is given in this section, reflecting SDC's perceptions as of the end of Task V. These perceptions were inevitably sharpened and modified during subsequent work, as indicated in Chapter III below.

A separate discussion of alternative computer-to-piano-keyboard interface design configurations and keyboard instrumentation is also included in this section.

1. Instructional Management System (IMS). This alternative provides for off-line use of a computer only. There is no equipment interface between the computer and the electronic pianos, and the computer can be remotely located.

The computer is not used as a direct teaching device. It does not store lesson materials; it does not display materials to the student; in fact, it does not communicate directly with the student in any way. Rather, it is designed to help the teacher make effective use of instructional resources already available; these may include textbooks, programmed materials, laboratory facilities, the teacher himself, and even CAI if that is available. For keyboard experience, the principal media envisioned are prerecorded lessons and tests on cassette player-recorders, and hard-copy visuals.

Course objectives are behaviorally defined, and test instruments are developed to measure performance on each objective. Most tests are in multiple-choice format, on forms that allow direct reading of student marks by an optical scanning device. Directions for taking the tests are contained on audio tapes which the children listen to over individual headsets. Each time a student completes a lesson unit, he receives a test. Tests are collected, optically scanned, and the results analyzed by computer. The computer scores each item and associates it with one or more behavioral objectives. Each objective is associated in the computer's memory with a criterion score representing the required criterion level, and a set of logical decision rules to generate prescriptive statements where performance falls below the criterion score.

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[*] These SDC-developed concepts were reviewed during a Keyboard Design Conference held July 31 and August 1, 1969. A list of attendees is shown in Appendix E.

The teacher receives one or more computer printouts about each test. The printout tells the teacher how far each student has progressed, what learning objectives he has successfully mastered, and what objectives are giving him difficulty. For each objective on which a student has failed to achieve mastery, one or more remedial activities are recommended. The computer may list specific units of exercise material to remedy each learning deficiency. Or, it may recommend teacher-conducted remediation.

In addition to the regular daily progress reports, which are based on individual tests, the computer also prints on-demand summary reports. These summary reports show each student's performance over a series of tests, and are designed to help teachers spot general trends and significant changes in performance.

As input, IMS requires information such as statements of objectives, tests and keys, a catalog of remedial prescriptions, and criteria for generating prescriptions. To provide diagnostic and prescriptive displays, IMS must have the test items, for each instructional objective, that assess performance on that objective; and the practice materials to be prescribed, should the student not meet the criterion for that objective.

The diagnostic and prescriptive information assists the teacher in making such instructional decisions as the following:

- The decision of how fast to pace instructional units with monitoring of individual student performance.
- The decision to regroup students by routine collection of performance data showing that if a child clearly doesn't belong in a given instructional group, he may be moved from one group to another.
- The decisions to modify the sequence of instruction, to revise instructional objectives, or to facilitate student achievement of instructional objectives.

Teachers may also use IMS data in parent-teacher conferences and for decisions in making student referrals. Although it may appear that these purposes can be achieved without computer-monitored instruction, it isn't possible for the teacher to monitor the detailed performance of large numbers of students without some kind of automated aids.

The main features of IMS then are: the regular testing routine; the constant focus on instructional objectives; the extension of the teacher's memory of available materials and activities appropriate to given objectives; and a systematic application. A flow chart of an experimental system developed by SDC is shown in Figure 7. Although a large-scale computer was used in the system shown, IMS can be successfully implemented with mini-computers.

2. MUSIC-MAN. MUSIC-MAN (MUSic Instruction by Computer MANagement) is a conceptualized design of a computer-managed music instruction system using a mini-computer interfaced to electronic pianos. It has essentially the same computer-management philosophy of operation as does IMS, but offers significantly more capability because of the on-line dynamics of the interface. It also represents an evolutionary step toward a fully interactive system.

a. Concept of Operation. Essentially, MUSIC-MAN allows the pupil to respond via a piano keyboard. These musical responses are analyzed by computer software. During the instruction, the computer indicates response accuracy. At the end of an instructional sequence, the computer assesses and prescribes the next sequence from an instruction materials file and provides the teacher with records of pupil progress.

MUSIC-MAN involves three distinct subsystems: hardware, software, and instruction. Each of these subsystems involves a number of functions. Some of these functions are interrelated or shared by two or all three of the subsystems.

The hardware subsystem includes several components, each one responsible for one or more function. The central component is a mini-computer. This computer has the necessary input-output (I/O) devices, interface devices, and supporting hardware. One separable component of the hardware subsystem is the audio-communicator. This amplifier system provides two-way communication between teacher and pupil. An inexpensive cassette tape recorder or tape player is provided at each pupil station.

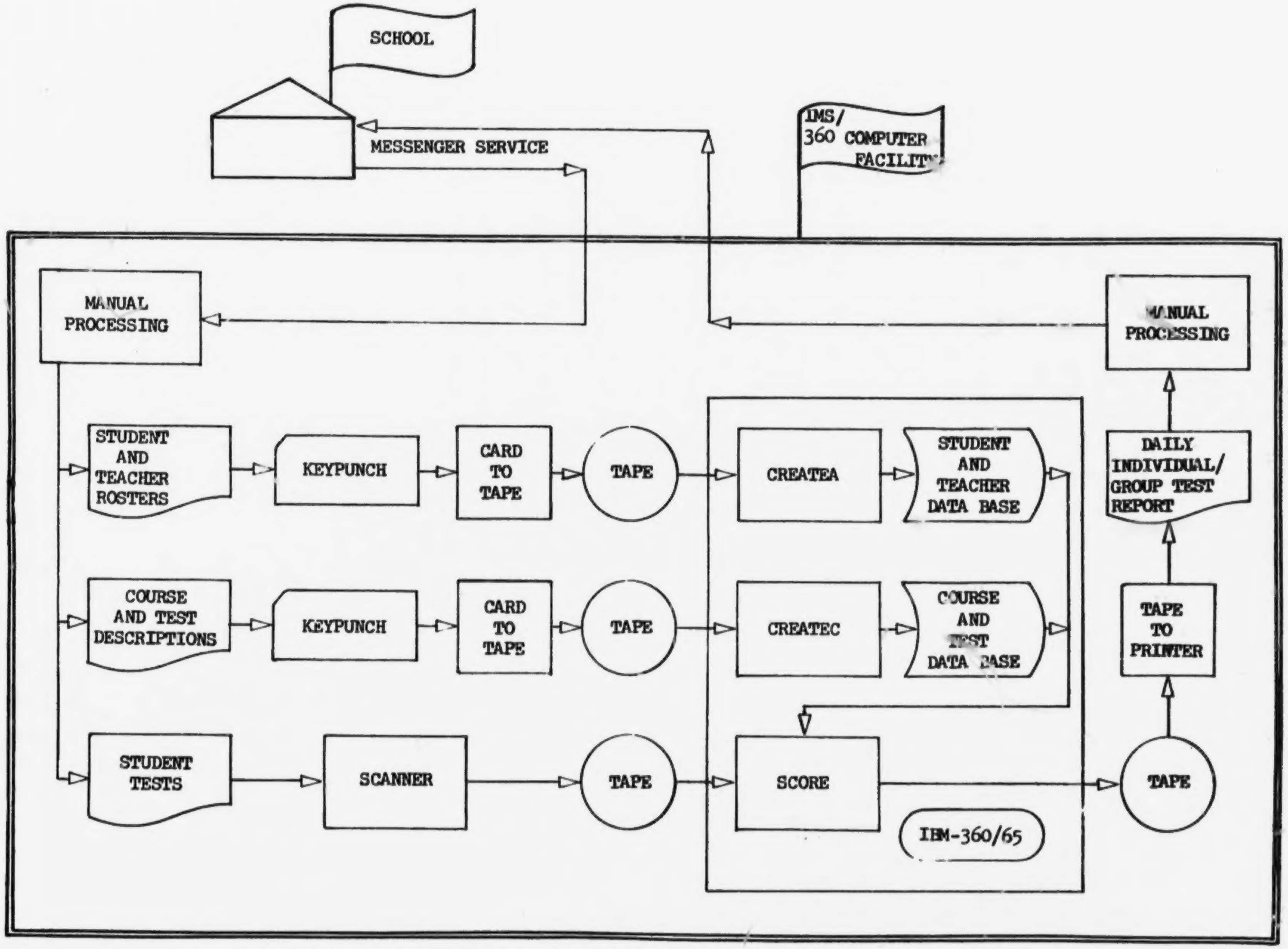

SCHOOL
MESSENGER SERVICE
IMS/ 360 COMPUTER FACILITY
MANUAL PROCESSING
STUDENT AND TEACHER ROSTERS
KEYPUNCH
CARD TO TAPE
TAPE
CREATEA
STUDENT AND TEACHER DATA BASE
COURSE AND TEST DESCRIPTIONS
KEYPUNCH
CARD TO TAPE
TAPE
CREATEC
COURSE AND TEST DATA BASE
STUDENT TESTS
SCANNER
TAPE
SCORE
IBM-360/65
TAPE
TAPE TO PRINTER
DAILY INDIVIDUAL/ GROUP TEST REPORT
MANUAL PROCESSING

Figure 7. Instructional Management System Information Flow

The software subsystem includes operational procedures and executive, response-analysis, decision-analysis, and prescriber programs. By suitable configuring of storage and appropriate programming of the Executive, a mini-computer may be used to process the programs on a time-allocation basis. By time-allocation, the response-analysis program serves as the major "real-time" program; the other programs respond under the control of the Executive at intervals which optimize utilization of computer time.

The executive program is responsible for system control--connecting input-output devices, monitoring interfaces, permitting changes in system operating procedures, accounting, and record-keeping.

The response-analysis program is responsible for polling, recording, and organizing pupil responses for subsequent action by the system. This program, in some respects, may be thought of as the "ear" of the system, since musical and other pupil responses may be obtained and processed via this program.

The decision-analysis program formats pupil responses (output from the response-analysis program) into decision information for subsequent processing. This subsequent processing takes the form of processing essential decision-analysis data.

The prescriber program relates the individual pupil's performance or progress to the available resources of the music instructional files. Reports are prepared that indicate each pupil's instructional characteristics, including comparisons with previous progress, progress status, suggested instructional sequences, diagnoses of difficulties, and other requirements that may become apparent during system testing.

The instructional subsystem comprises text and visual materials, audio recordings on cassettes, and vocal instructions given by the teacher. Since a primary emphasis is individualized instruction, a wide variety of levels and types of instructional materials and methods is indicated. The actual test and visual materials would be contained in hard-copy format, with a suitable index to reference each lesson element or sequence. The audio cassettes are also indexed so that each pupil may be referred to appropriate models and music for listening. The physical storage of instructional materials requires a filing system that needs to be well-organized and flexible.

The size of the instructional materials file will depend on actual instruction design. Efficient organization is needed to efficently find or replace a lesson sequence. Felxibility will be required to enable the teacher to modify the content of instruction and to allow for expansion of the types or levels of materials. The inclusion of audio materials for both instruction and appreciation is integral to the MUSIC-MAN concept, as these materials can make aural (i.e., directly musical) experiences fully available to each pupil. The instructional materials file is a special-purpose music library with broad coverage, purposefully directed toward maximum individualization of both instruction and enjoyable and stimulating musical experiences.

b. Equipment Configuration. The equipment configuration includes all hardware needed for an operational system. The hardware should provide:

(1) A means of indicating a lesson or a sequence for an individual lesson-plan by hardcopy printer or other display device.

(2) Response collection and analysis. A piano keyboard input via an interface to intermediate or core storage. Subsequent analysis of the response with respect to 8-note melody, three sequential 3-note chords, and rhythm/tempo recorded to 0.05 second tolerance seem reasonable parameters.

(3) Comparison of student response with correct, anticipated incorrect, or unanticipated incorrect models of 8-note melodies, three sequential 3-note chords, and rhythm/tempo correct to 0.05 second. These responses may be stored and controlled by the response-analysis program.

(4) Decision processing of results of individual melodic, harmonic, and rhythmic comparisons. The output of this processing step should be organized for decisions to accelerate student progress, to continue at the same rate, to slow down, to remediate, to provide practice or exercises, to review, or to call the teacher.

(5) Evaluation of student progress. The student should receive direct information regarding his progress. This information should be in a response-specific form, that is, identifying good responses (separating them from the "bad"). The system should provide evaluative data reduction so that the general pattern of student progress may be explicitly displayed with respect to lesson type, expected progress, and class standing. Evaluation as an extrinsic reward should be deemphasized (no "grades").

Each of these five central requirements will need to be within the hardware capability. Figure 8 is a block diagram of the equipment configuration. The hardware devices include the following types and specific equipment:

(1) Input (Per Pupil Station)

Electronic Piano
Headset and Microphone
Pupil Operations Panel

(2) Processing (Per 16 pianos)

Interface devices
Computer
  16K core memory, 1-microsecond memory cycle minicomputer
Disk or Tape Storage
  2 million bytes

(3) Output

Printer
  Small "economy" model (if the noise level is too high, substitution of a non-impact printer will be considered).
"Tub" file or shelf file system for storage of instructional materials.
Tape-recorder or player, (inexpensive) cassette type (1 for each pupil, included in console)
Teacher Console Piano with communicator (modified as required)
System Input Device
  Typewriter-type keyboard with instructional system update programming capability.

c. Software Requirements. Basically, four programs have been outlined for the computer software system: executive program, a response-analysis program, a decision-analysis program, and a prescriber program. Each of these four basic programs performs specific input, control, processing, and output functions.

(1) Executive Program. This program controls all other programs in the MUSIC-MAN instructional management system. The Executive controls device connection, system time relations, program calls, and system accounting.

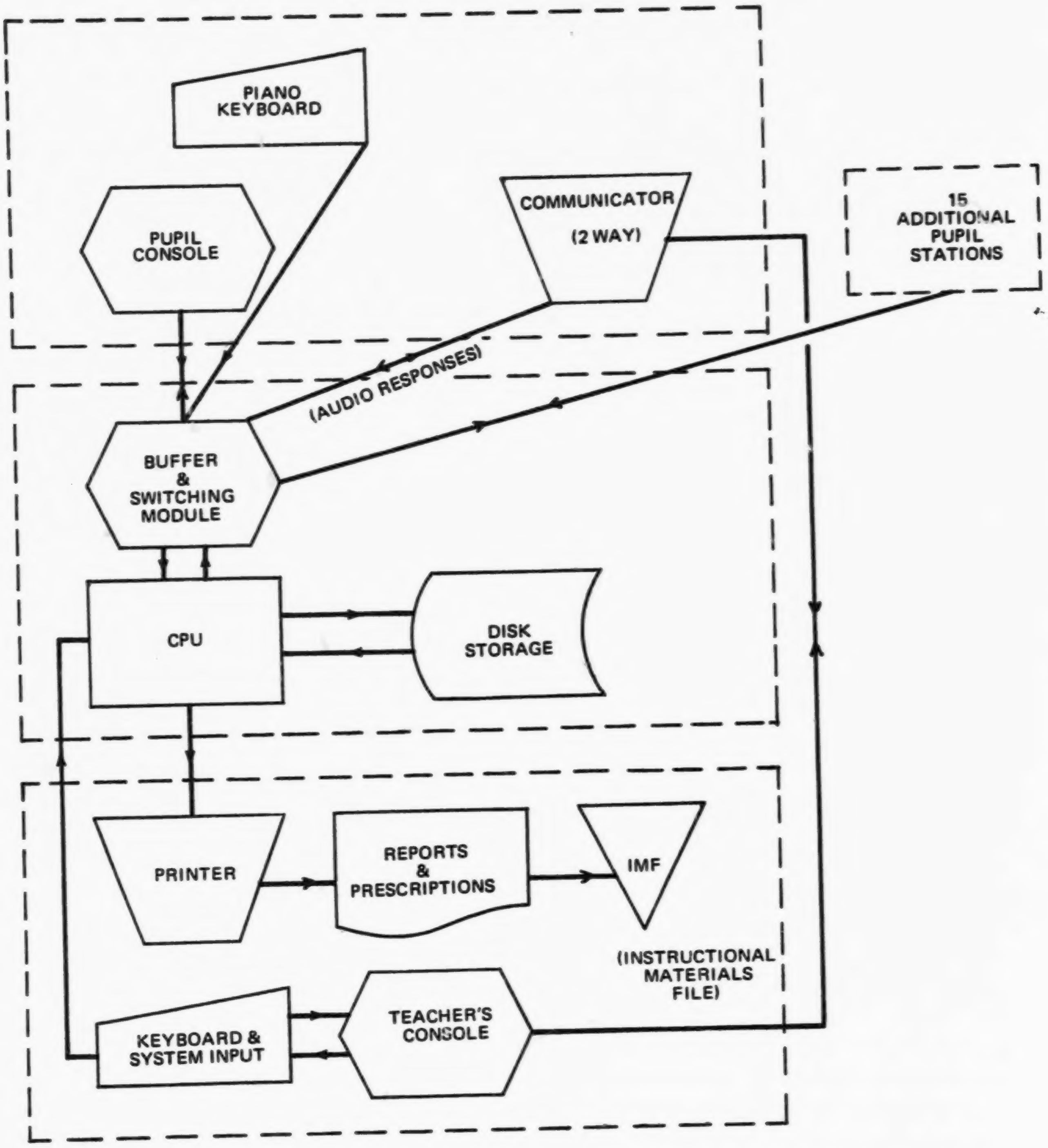

PIANO KEYBOARD
PUPIL CONSOLE
COMMUNICATOR (2 WAY)
15 ADDITIONAL PUPIL STATIONS
(AUDIO RESPONSES)
BUFFER & SWITCHING MODULE
CPU
DISK STORAGE
PRINTER
REPORTS & PRESCRIPTIONS
IMF
(INSTRUCTIONAL MATERIALS FILE)
KEYBOARD & SYSTEM INPUT
TEACHER'S CONSOLE

Figure 8. MUSIC-MAN Hardware Configuration

Principle 1: The Executive will permit the response-analysis program to have system priority.

Principle 2: The Executive will interrupt the response-analysis program during any period of minimal activity, so the decision-analysis program may operate.

Principle 3: The Executive will not interrupt the decision-analysis program until processing is complete on a defined record.

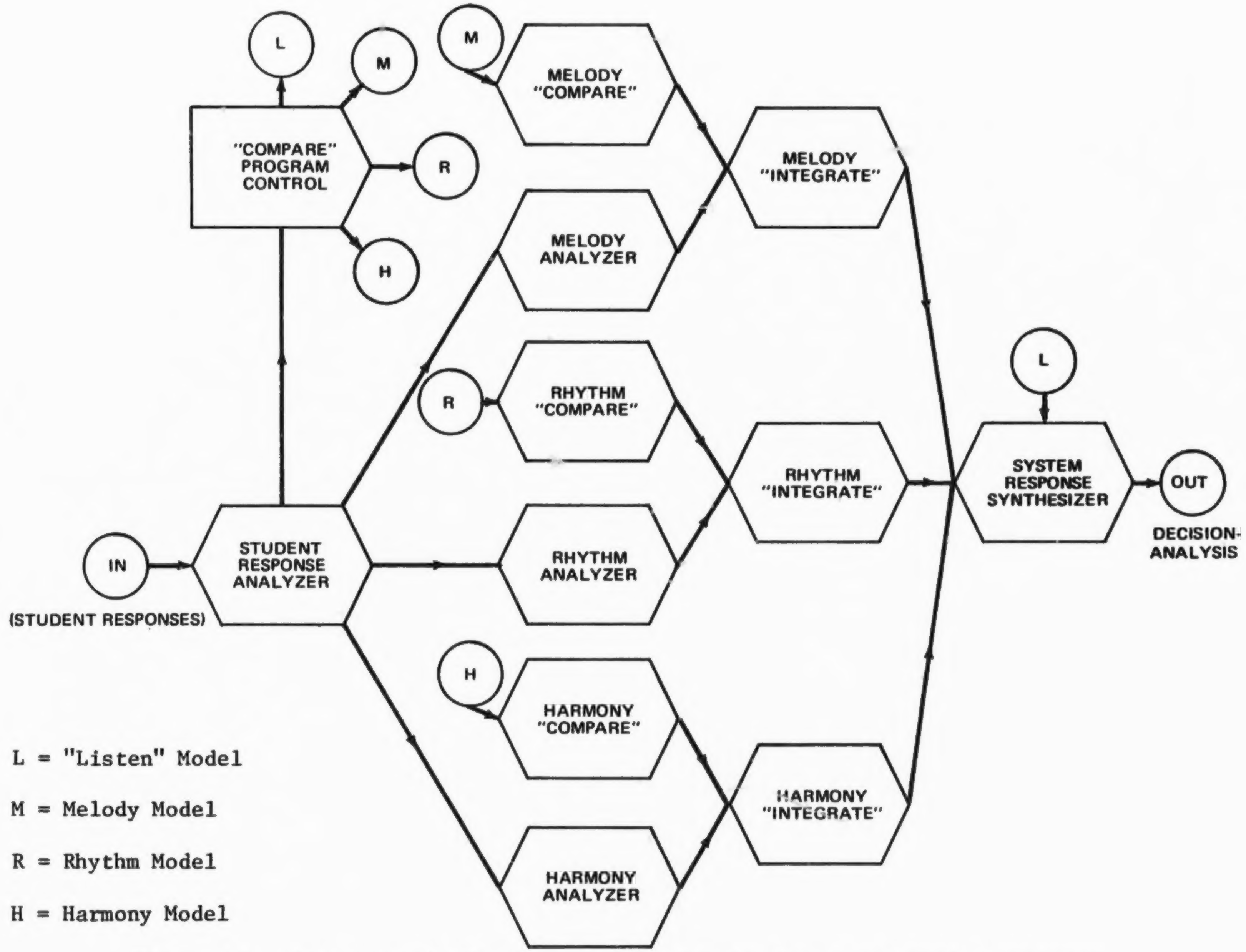
Principle 4: The Executive will allow the system operator to call the prescriber program for system starts (roll-call) and for system close-down (evaluation, prescription, and report-writing).

Principle 5: The Executive will monitor system status and interrupt any malfunctioning terminal.

Principle 6: The Executive will provide diagnostic messages to the system monitor concerning any program errors or system failure.

Thus, the Executive Program performs the main operating system functions of the software system. The Executive should be designed so that system modification is possible by updating or correction. A back-up of the executive should be readily available if the program is destroyed by some malfunction.

(2) Response Analysis Program (Figure 9). The response-analysis program is the principal on-line program and, as the name suggests, performs the analysis of all pupil responses. Since many of these pupil responses are rendered via the keyboard of the pupil piano, the major analysis comprises the acceptance routine of data input in the form of melody, harmony, and rhythm. These inputs are then "resolved" in processing. The resolution routines are principally the processing of encoded pupil input and comparison with models of anticipated responses. The comparisons are then "integrated" for mediation or remediation by indicator lights on the student console. The program then transfers to a system-response routine for output to the decision-analysis program.


L
M
"COMPARE" PROGRAM CONTROL
R
H
M
MELODY "COMPARE"
MELODY ANALYZER
MELODY "INTEGRATE"
R
RHYTHM "COMPARE"
RHYTHM ANALYZER
RHYTHM "INTEGRATE"
H
HARMONY "COMPARE"
HARMONY ANALYZER
HARMONY "INTEGRATE"
IN
(STUDENT RESPONSES)
STUDENT RESPONSE ANALYZER
L
SYSTEM RESPONSE SYNTHESIZER
OUT
DECISION-ANALYSIS

L = "Listen" Model

M = Melody Model

R = Rhythm Model

H = Harmony Model

Figure 9. Response-Analysis Program (Music Instructional Resolver)

Pupil feedback is obtained via the response-analysis program. The program processes pupil responses by comparing them with stored models. The response-analysis program provides immediate system response to the playing activities of the pupil by means of a series of panel lights on the pupil's piano. Possible panel lights are shown in Figure 10. In an actual system, a considerably more sophisticated set of signals would probably be desirable. Lights would be turned on as required to provide feedback to pupils. Additionally, the brightness or frequency of an indicator lamp could be controlled to show a spectrum of response criteria.

A typical lesson sequence could be:

(1) The "PLAY" light comes on.

(2) Pupil plays the lesson segment as directed on the hard-copy music, test, or picture (4-5 seconds).

(3) The response-analysis program processes the pupil response.

(4) The "TRY AGAIN" light comes on.

(5) Pupil tries again.

(6) The response-analysis program processes the pupil response.

(7) The "GOOD" light comes on.

(8) The "PLAY" light comes on.

(9) Pupil continues lesson sequence.

(10) The response-analysis program processes the pupil response.

Other pupil responses may generate alternative patterns of feedback lights. Limits or other criterion values may be set on time, number of errors, or response latency in the analysis program, so that the response lights should be responsive to varying patterns of pupil responses. For example, the use of the TRY AGAIN light probably should be restricted to two or three trials only.

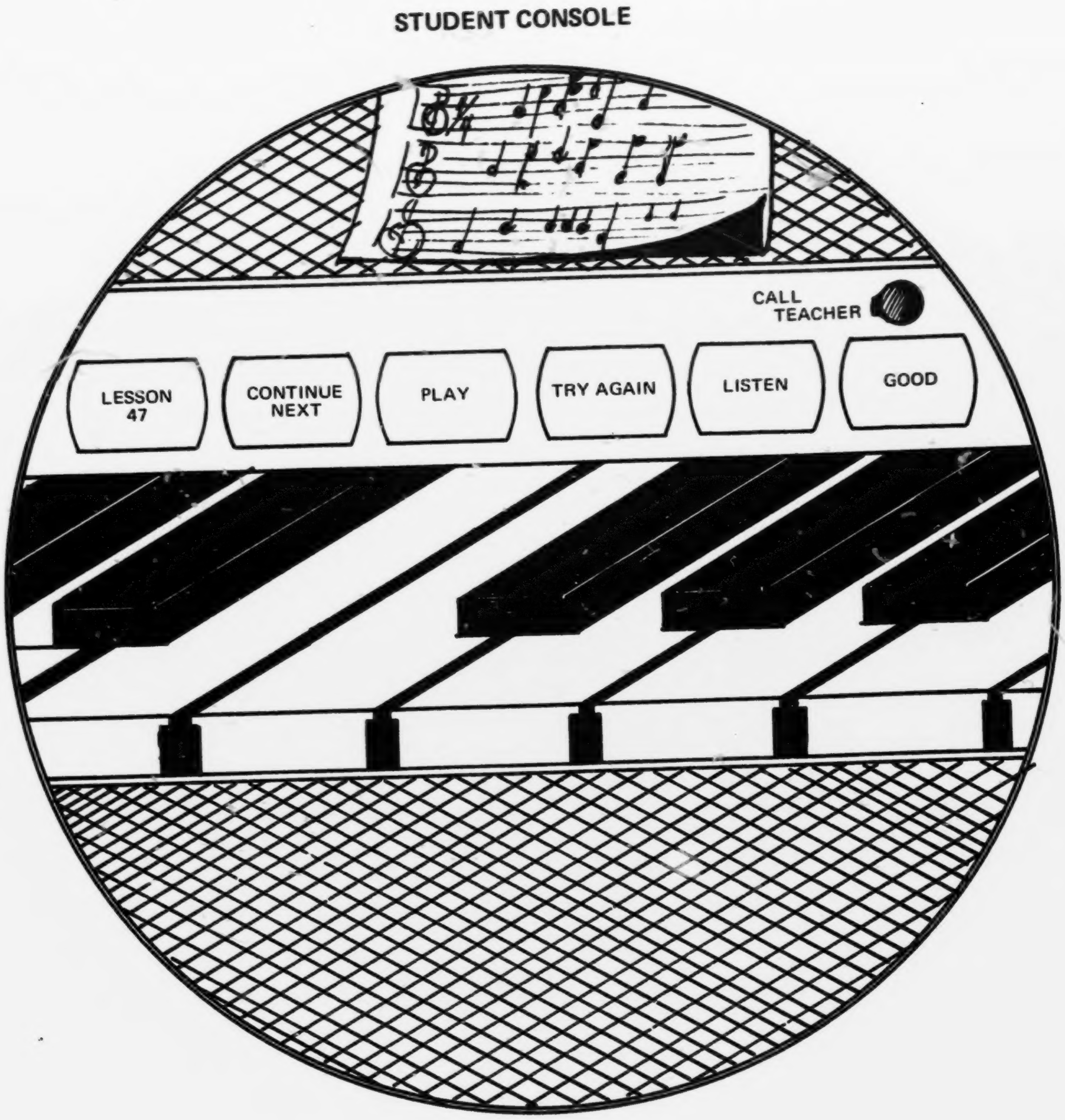

STUDENT CONSOLE
CALL TEACHER
LESSON 47
CONTINUE NEXT
PLAY
TRY AGAIN
LISTEN
GOOD

Figure 10. Sample Stimulus and Feedback Signals

Varying pupil responses will pose a significant programming problem, since there will probably be a large number of fairly complex response patterns requiring resolution into only a few system response indicators. These circumstances will require a high degree of instructional programming ingenuity.

(3) Decision-Analysis Program. This program accepts, under the control of the Executive, the results of resolved responses. The data are then processed by reduction and subsequent comparison with pupil response listings and instructional logic routines. These routines will contain models of instructional sequences to control the translation of data into a form acceptable to the prescriber program. The models will be formulated around decision rules that permit individualization to the extent possible, so that processing by the prescriber program is possible on unique pupil and instructional factors.

(4) Prescriber Program. This program is essentially a compiling program that permits prescribed instruction sequences (accelerate, practice, drill, and remediate) to be identified from the file. For example, if REMEDIATION for a given pupil is indicated by the decision-analysis program, the prescriber will control the prescription of an appropriate lesson. The program will process this prescription and generate a report item and any associated information. All pupil prescriptions will be processed to provide a concise and readable report to the teacher. The prescriber program will provide precise indexing information so that the lesson sequence, either text or cassette recording, may be extracted from the music instruction file.

(5) Music Instruction File. This computer-managed software component is a preprinted file or library carefully indexed so that lesson sequences, visual, and audio cassette or other materials may be easily extracted or replaced as indicated by the prescriber program. The teacher or the pupil will access the file based on the report output from the prescriber program. Modifications may be made to the file by inserting the hardcopy or audio recording and entering the index of the item into the prescriber program.

3. Advanced CAI System

a. Concept of Operation. This is a fully-automated system in which the presentation of both aural and visual materials is under the control of a computer. The computer in turn is completely responsive to the pupil's learning performance in the way it presents the material. Appropriate visual material will be presented via slides, when fixed displays are called for, or by means of computer-generated displays, where dynamically changing displays are necessary.

The CAI program will be able to "judge" the pupil's piano responses, as well as his responses via the response panel, and make decisions based on both his previous performance record and his most recent response. These decisions will determine whether the next "frame" in a lesson sequence is to be presented, whether remedial material is to be given, or whether the pupil may be skipped ahead. The program's ability to make these decisions enables each pupil to move through a lesson sequence at his own speed and according to his individual ability. The program will also record each pupil's performance record for the day. A hard copy of these records will be available to the teacher.

The organization of the audio material (as well as the coordinated visual presentations) is determined by the lesson designer, who must anticipate individual students' varying abilities, interests, and modes of learning. An example of an organizational structure is one that consists of three parts: a "main lesson frame set," an "exploratory lesson frame set," and a "remedial lesson frame set." The first of the sets contains lesson material organized so that presentation of new material is dependent on the comprehension and retention of previously presented material. A student may move steadily through the main lesson frame set, progressing at his own pace.

When a student misses answers to questions in this set, or takes too long to make a correct response, or both, he is branched by the CAI program, which has been inspecting his response record, to the remedial lesson frame set. When he is ready to continue the main lesson frame set again, the CAI program branches him back to the appropriate place in the main lesson set stream. As he progresses through the main lesson frame set, his answers are continuously monitored for unanticipated or insightful content. When such unanticipated or insightful content is found, the exploratory lesson frame set is brought into play in order to evaluate the response. Then the program will either branch the pupil further ahead into the main lesson frame set or continue to explore, reinforce, and further explicate the insight prior to skipping the pupil further along to a more advanced part of the main lesson frame set.

b. Equipment Configuration. A sample configuration could consist of a central computer operating in a time-shared mode and containing the basic programs. Up to 30 student stations could communicate with the central computer via a minicomputer acting as a buffer or via 10 separate buffers (one per 3 student stations). Each of the 30 student stations contains the following equipment:

(1) An electronic piano.

(2) A Digivue or Plasma-See-Thru Display Panel (or equivalent).

(3) A response panel.

(4) Earphones.

(5) An audio source (tape recorder, disk player or other type).

(6) A set of visual materials (on slides, microfiche or other media).

(7) A set of audio materials consisting of pre-recorded presentations of musical/spoken material.

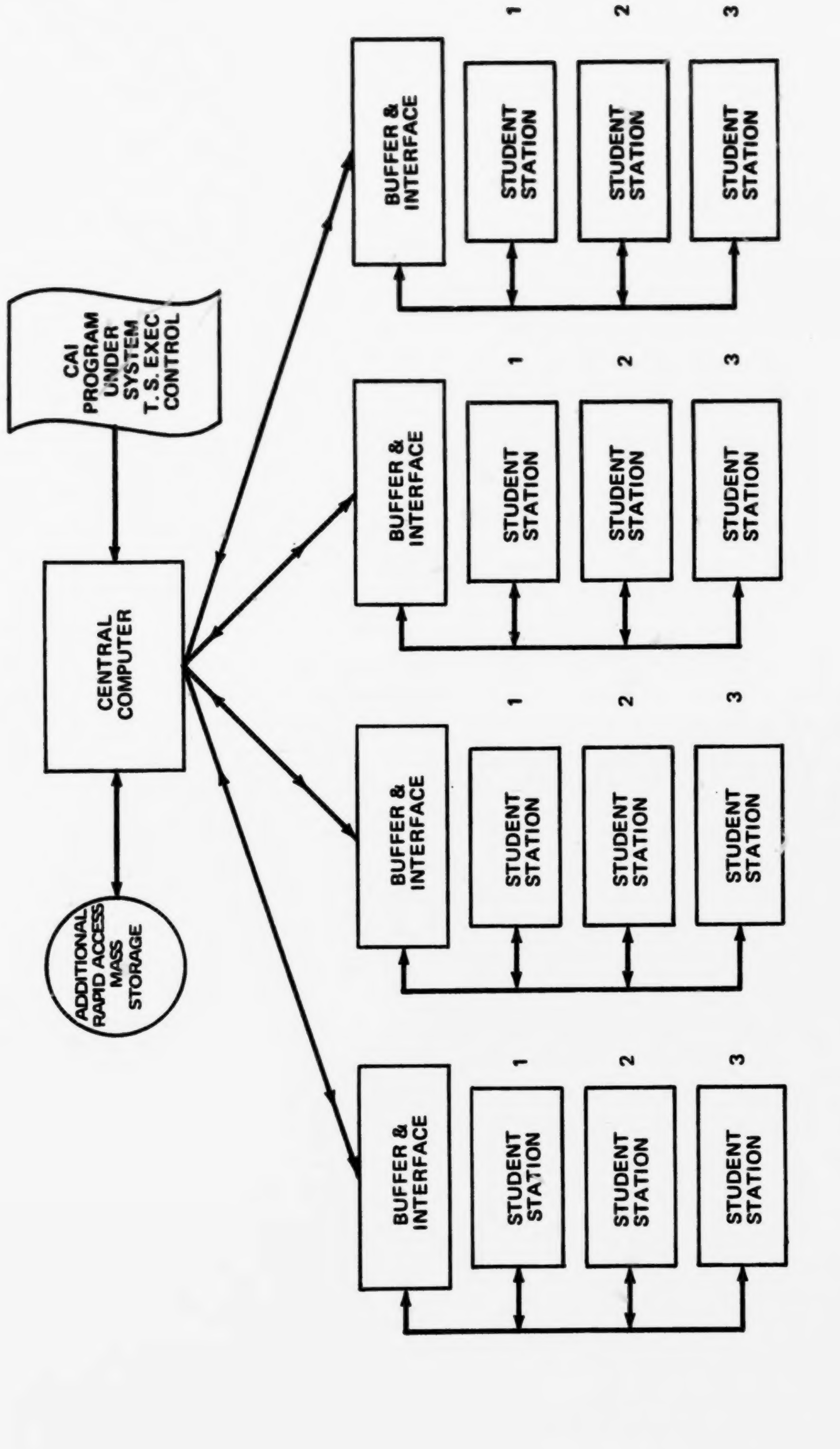
Figures 11 and 12 illustrate the relationship these elements have in the system.

Taking these elements one by one, the next paragraphs discuss what role each plays in the system.

(1) The electronic piano is wired so that whatever is played on it by the pupil (in response to requests by the CAI program) is passed on to the central computer via the buffer. The played response is then ready for analysis by the CAI program.

(2) The display panel is also wired to the buffer and, through it, receives any computer-generated visual displays. The panel is also connected to a slide or microfiche projector so that computer-selected visual material may be shown on it. Computer-generated displays can be superimposed upon fixed slide or microfiche displays in order to achieve a maximum display flexibility.

(3) The response panel's role is to allow the student to give yes or no replies or reply to a multiple-choice-type question. The reply is made by pushing the appropriate button. The "PLAY" (or "READY") button is pushed only when the pupil wants


ADDITIONAL RAPID ACCESS MASS STORAGE
CENTRAL COMPUTER
CAI PROGRAM UNDER SYSTEM T.S. EXEC CONTROL
BUFFER & INTERFACE
STUDENT STATION
1
2
3

THERE WILL BE 10 BUFFER/INTERFACE UNITS AND EACH ONE WILL SERVICE 3 STUDENT STATIONS FOR A TOTAL OF 30 STUDENT STATIONS.

Figure 11. Fully Automated System Equipment Configuration

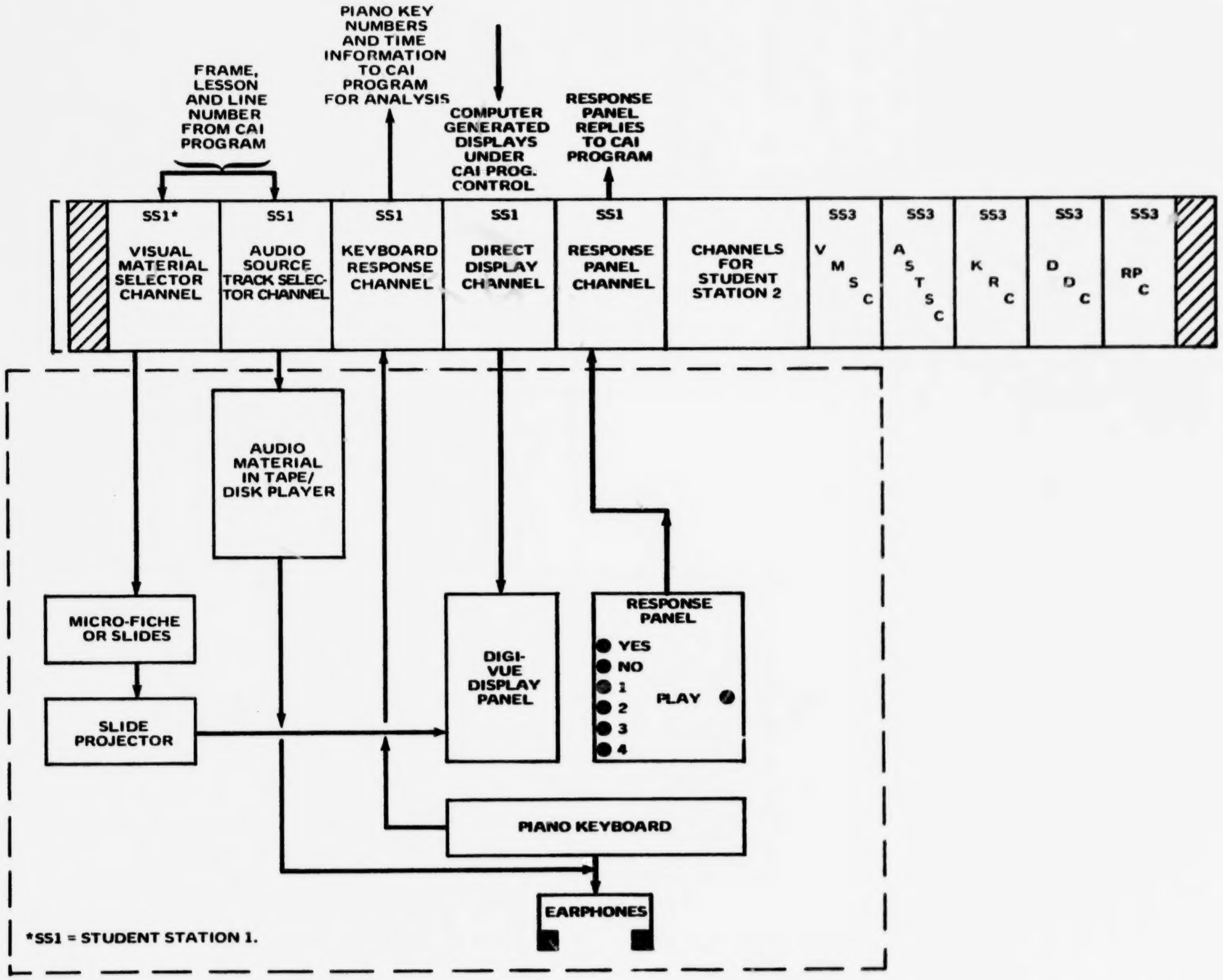

FRAME, LESSON AND LINE NUMBER FROM CAI PROGRAM
PIANO KEY NUMBERS AND TIME INFORMATION TO CAI PROGRAM FOR ANALYSIS
COMPUTER GENERATED DISPLAYS UNDER CAI PROG. CONTROL
RESPONSE PANEL REPLIES TO CAI PROGRAM
SS1*
VISUAL MATERIAL SELECTOR CHANNEL
SS1
AUDIO SOURCE TRACK SELECTOR CHANNEL
SS1
KEYBOARD RESPONSE CHANNEL
SS1
DIRECT DISPLAY CHANNEL
SS1
RESPONSE PANEL CHANNEL
CHANNELS FOR STUDENT STATION 2
SS3
V M S C
SS3
A S T S C
SS3
K R C
SS3
D D C
SS3
RP C
AUDIO MATERIAL IN TAPE/ DISK PLAYER
MICRO-FICHE OR SLIDES
SLIDE PROJECTOR
DIGI-VUE DISPLAY PANEL
RESPONSE PANEL
YES
NO
1
2
3
4
PLAY
PIANO KEYBOARD
EARPHONES
*SS1 = STUDENT STATION 1.

Figure 12. Fully Automated System Student Station and Buffer/Interface Details

to have the computer program inspect what he plays on the piano. Once this button is pushed an interrupt is sent to the central computer for analysis by the CAI program.

(4) The earphones are worn by the student and through them he hears the pre-recorded instructional and musical material. He can listen to himself play through them.

(5) The audio source is the device that contains and plays the pre-recorded instructional and musical material for the student. The material is organized as a series of variable length pre-recorded lesson frames. Each frame is uniquely identifiable and must be rapidly accessible (within 2 seconds maximum) on a random basis. The CAI program determines which frame is to be accessed and played for the student. The device itself could be a random-access tape player or a random-access disk player.

(6) The visual materials will be slides or microfiche images arranged in a suitable random-access projection device. Each slide or microfiche image will also be uniquely identifiable and accessible, under program control, on a coordinated basis with the audio material.

The CAI component must be able to do the following when interacting with a student:

(1) Analyze individual student keyboard response and, upon the basis of the "correctness," "incorrectness," or "adequacy" of the particular response, decide what frames to present to the student next. The same must be done for answers coming from the response panel. The decisions the CAI program makes concerning what subsequent course to follow for any one student must be based not only on present responses but on each student's past history of response performance. The requirement implied here is that the CAI program must have access to and maintain such a history for every student.

(2) Present to each student, according to his progress through the lesson set, the appropriate aural lesson frame coordinated with accompanying visual displays (if any are required).

Other capabilities required of the CAI software concern assistance given to the instructor or lesson designer in preparing a set of lesson frames and in evaluating their contents subsequent to their preparation. This twofold task will be accomplished using the on-line interactive mode with the central computer.

Two modes of interactive operation are required here. The first is the "generate" mode, during which new lesson frame material is constructed. The second is the "evaluation" mode, during which the instructor can try out the lesson material and modify it as he sees fit. The product of such an exercise will be a "script" that is translatable to audio storage addresses and visual storage addresses. These addresses indicate, on a frame-by-frame basis, the locations of the audio and visual material the program has to fetch and present to the student.

In addition to the foregoing programs, utility and support programs will be needed to (1) generate music models for comparison against played models and create a library so that the necessary models can be included in the frame-by-frame script; and (2) allow modifications of previously assigned addresses when material is deleted or inserted during the modification process. These utility and support programs should be operable in a batch mode.

4. Keyboard Instrumentation and Interface Design Alternatives. The interface is probably the most critical and novel item for consideration in assessing the feasibility of a computer-assisted keyboard instruction system. For that reason, the advantages and disadvantages of the principal factors affecting interface design need careful analysis. Among these factors are costs, which are here estimated on the basis of parts costs for an interface constructed from available module boards and electrical components. Exact costs cannot be determined without a complete design specification. (For a set of preliminary functional specifications, see Appendix F.)

Electronic Piano Instrumentation

The costs of instrumenting the piano itself are independent of the interface technique used between the piano and the computer. There are three instrumentable keyboard parameters: (1) key selection, (2) duration of key depression, and (3) intensity of key depression. Instrumentation for intensity sensing has tentatively been ruled out.[1] Instrumentation for the remaining two parameters (key selection and duration of depression) is susceptible to two techniques, either of which would provide the basic information needed for processing--the time sequence of notes generated:

a. Addition of Switches Under the Keys. The Wurlitzer Company estimates that the manufacturing cost of incorporating a switch under each key would be $20 per piano, for all 64 keys. Filters, logic, and wiring would add roughly $6 per key.

b. Tone Sensing. The Wurlitzer Company estimates that modifying their piano to sense individual tones would cost approximately $75 per piano. The resulting output from the tone sensors would be about 100 millivolts RMS. Consequently, amplifiers, peak detectors, and logic would be needed which would add roughly $15-20 per key to the costs. This technique offers the capability of measuring intensity (which has been tentatively ruled out); it also insures detection as to whether a note has actually been sounded (using the switch technique described above, it would be possible to gently effect switch closure and opening without producing sound).

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[1] Sensing the intensity of key depression by hardware and interpreting it in the software would be desirable since the concepts of loud-soft and accent groupings are integral components of the instructional process at the elementary-school level. However, instrumenting this parameter would approximately double the cost of instrumenting the electronic piano because separate switches and wiring would be required for that parameter alone. Additional costs would be incurred in the interface between the electronic piano and the computer, in computer storage, and in software. At the Task V design meeting on July 31-August 1, it was the consensus of the music consultants present that instrumenting this parameter would not be essential at the elementary-school level. Interest in having this capability at the higher-education level was expressed by some of the music consultants. An experimental piano has been developed by P. R. Dijksterhuis and T. Verhey of the Netherlands that has a built-in electronic capability for outputting intensity information. It is a matter of conjecture at this point as to whether an electronic piano having that capability can be manufactured at marketable cost.

The advantages of tone sensing do not offset its high cost. Therefore, incorporation of switches is the alternative that has been chosen. In the Task V design meeting held on July 31-August 1, 1969, a consensus was reached that it is not necessary to instrument all keys. Instrumentation of the middle range of the keyboard would easily cover the voice range of elementary-school students as well as the overwhelming preponderance of music notes displayed and used in instruction. Therefore, the design alternative chosen is switch instrumentation of 32 keys in the middle range of the keyboard. This, of course, does not preclude use of the entire keyboard in manual mode. On the above basis, the cost of instrumenting the piano itself would be approximately $200.

Electronic Piano-to-Computer Interfaces

The discussion that follows assumes a mini-computer with a 16-bit word length, 16K core memory, and a memory cycle of 1 microsecond or less (representative mini-computers in this class are Honeywell's DDP-516 and Scientific Data Systems' Sigma 2). Also assumed are 16 electronic pianos, each instrumented with 32 keys (a total of 16 x 32 = 512 keys). For reasons discussed below, a mini-computer with a slower memory cycle would be infeasible.

The interface techniques possible are divided into two classes: non-buffered and buffered. Within these two classes there are two subclasses: time-driven and state-driven. In general, the tradeoff involved is central processing time versus the complexity of logic external to the computer.

a. Time-Driven, Non-Buffered Polling Technique. Using this technique, the computer software would be responsible for examining each key on each piano every 50 milliseconds or less. It is estimated that examining 512 keys would occupy most the time of a mini-computer having a memory cycle of 2 or more microseconds, leaving little or no time for instructional processing. With a 1 microsecond mini-computer, it is estimated that half of the CPU (central processor unit) time would be available for other processing. Polling would consist of selecting each piano in succession and reading into the computer the state of the 32 keys (up or down) as two 16-bit words. These key states would be used to build program tables (preferably a separate table for each piano) showing key depression history on a time basis. The hardware configuration for this technique is shown in Figure 13. The basic programming flow is charted in Figure 14. The Decode Module decodes the polling message from the computer.

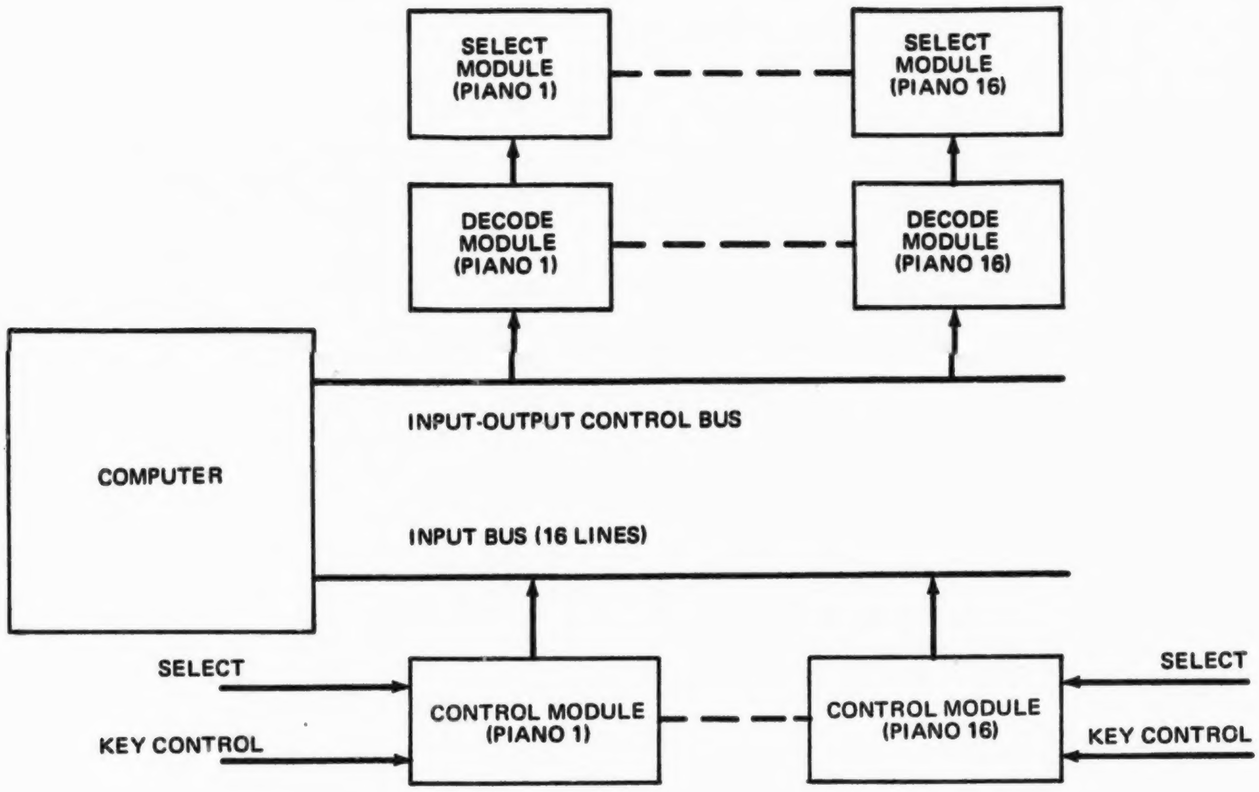

SELECT MODULE (PIANO 1)
SELECT MODULE (PIANO 16)
DECODE MODULE (PIANO 1)
DECODE MODULE (PIANO 16)
COMPUTER
INPUT-OUTPUT CONTROL BUS
INPUT BUS (16 LINES)
SELECT
KEY CONTROL
CONTROL MODULE (PIANO 1)
CONTROL MODULE (PIANO 16)
SELECT
KEY CONTROL

Figure 13. Polling Technique Keyboard Interface Block Diagram

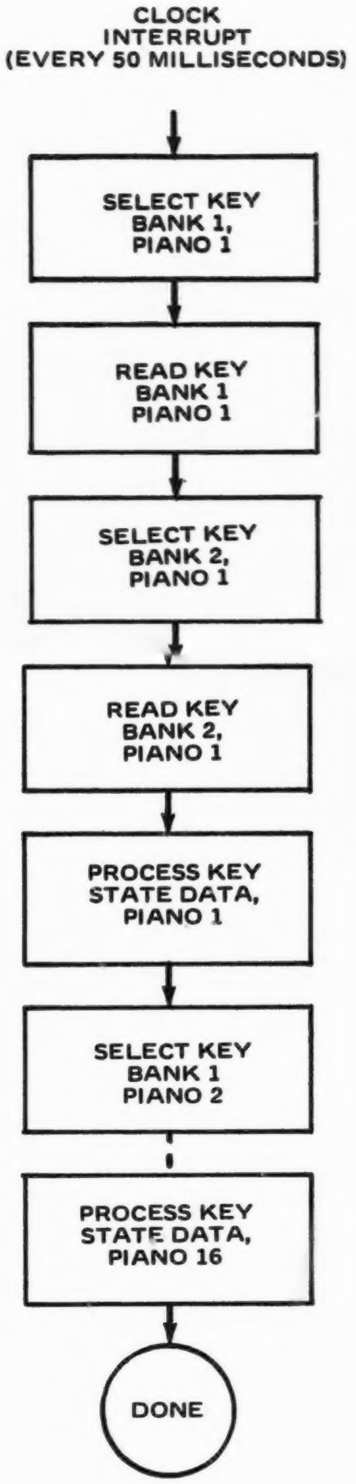

CLOCK
INTERRUPT
(EVERY 50 MILLISECONDS)
SELECT KEY BANK 1, PIANO 1
READ KEY BANK 1 PIANO 1
SELECT KEY BANK 2, PIANO 1
READ KEY BANK 2, PIANO 1
PROCESS KEY STATE DATA, PIANO 1
SELECT KEY BANK 1 PIANO 2
PROCESS KEY STATE DATA, PIANO 16
DONE

Figure 14. Polling Technique Flow Chart

The Select Module informs the Control Module that the particular piano (1, 2, etc.) is being polled. The Control Module determines state changes in keys and transmits that information to the computer. The estimated costs are $20 for the Decode Module, $30 for the Select Module, and $200 for the Control Module. For 16 pianos, the cost of this interface would then be approximately $4000.

b. State-Driven, Non-Buffered Technique. Using this technique, each piano would monitor itself and interrupt the computer when a state change occurs. The advantage of this technique over the polling technique is less CPU time; it is estimated that this technique would require less than 10 percent of the processing time of the computer. Thus, more time would be available for instructional processing. However, the price paid is added complexity and costs in the interface. The essential difference in the hardware (compared to the polling technique) is the addition of a state change sensor for each piano, the estimated cost of which would be $320 per piano. The hardware configuration for this technique is shown in Figure 15. The basic programming flow is charted in Figure 16. The state change sensor would send an interrupt to the computer when any state change occurs in key depressions. Speed of interrupt handling would be increased by having a separate interrupt line for each piano. Since computers normally are configured with only one interrupt line, there would be an added cost of approximately $2000 for a computer configured with separate interrupt lines. It is probable, but not certain, that one interrupt line would be sufficient. Using one interrupt line, the cost of this interface for 16 pianos would be approximately $9000.

c. Buffered Interfaces. For this discussion, it is assumed that the interface must always be ready to accept a student response. That is, after the presentation of instructional material, the student may start responding whenever he wants to. He needs no "PROCEED" signal. This requires that each piano have its own buffer storage.

(1) Time-Driven Buffered Interface. This technique is related to the polling technique used for a non-buffered interface. As the student is responding, the state of his keyboard is stored in the buffer memory every 20 milliseconds. Enough memory must be provided to store an entire student response. Using 32 keys per piano, 1 bit per key, 1600 bits of storage would be required for every second of response. If the maximum response duration is 20 seconds (as an example, "Love Somebody" can be played at a moderate tempo in about 10 seconds), 32,000

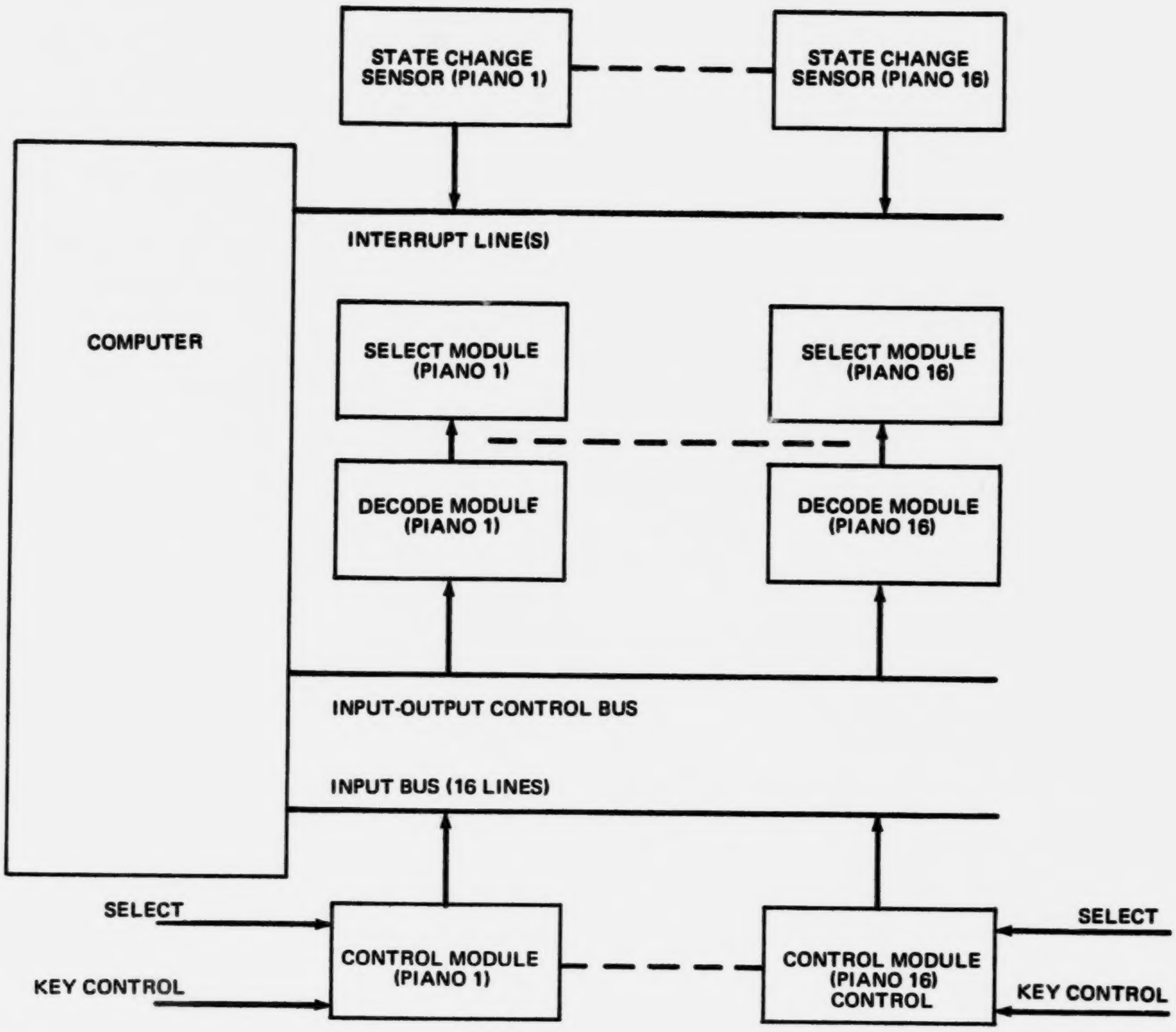

STATE CHANGE SENSOR (PIANO 1)
STATE CHANGE SENSOR (PIANO 16)
COMPUTER
INTERRUPT LINE(S)
SELECT MODULE (PIANO 1)
SELECT MODULE (PIANO 16)
DECODE MODULE (PIANO 1)
DECODE MODULE (PIANO 16)
INPUT-OUTPUT CONTROL BUS
INPUT BUS (16 LINES)
SELECT
KEY CONTROL
CONTROL MODULE (PIANO 1)
CONTROL MODULE (PIANO 16) CONTROL
SELECT
KEY CONTROL

Figure 15. State Change Technique Keyboard Interface Block Diagram

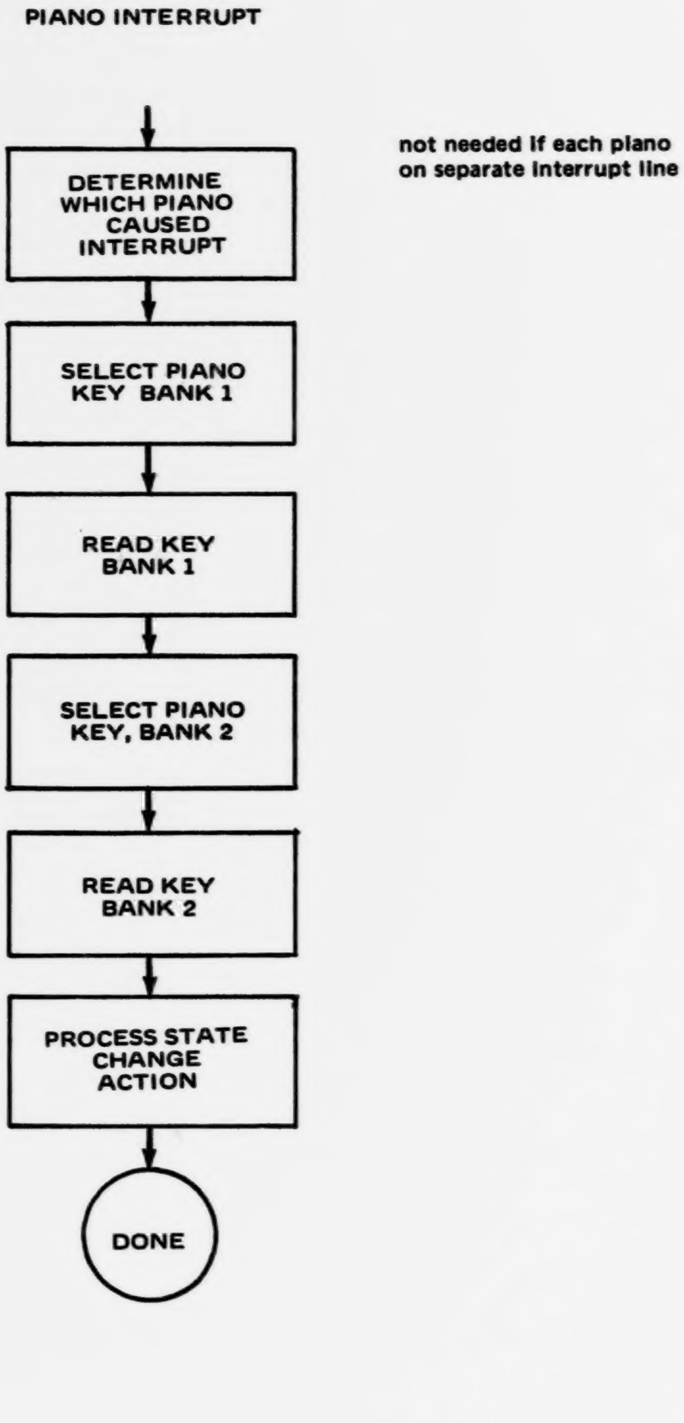

PIANO INTERRUPT
DETERMINE WHICH PIANO CAUSED INTERRUPT
not needed if each piano on separate interrupt line
SELECT PIANO KEY BANK 1
READ KEY BANK 1
SELECT PIANO KEY, BANK 2
READ KEY BANK 2
PROCESS STATE CHANGE ACTION
DONE

Figure 16. State Change Technique Flow Chart

bits would be required. The following components would be required if the buffer is implemented with a core memory:

(a) Core memory--32,000 bits per piano; $2500 per piano.

(b) Core memory control, including memory-address counter, buffer-full detector, and clock initialization control; $400 per piano.

(c) Keyboard-to-buffer interface, including keybank selection; $400 per piano.

(d) Buffer-to-computer interface; $400 per piano.

Relatively fast buffer core memory is used here to allow compatibility with the computer core memory. The buffer may be directly addressable by the computer or may be read as a block. In the latter case, $5000 would be added to the cost of the computer. The hardware configuration for this technique is shown in Figure 17.

The time-driven buffer technique also lends itself to the use of a synchronous memory, such as a head-per-track drum (a head-per-track disk or a delay line could also be used). If this were used, the interface would require the following components:

(a) Drum memory shared among 16 pianos; $10,000

(b) Drum memory control, including timing generators, location counter, buffer-full detector, and initialization control; $600 per piano.

(c) Keyboard-to-buffer interface, including keybank selection and parallel-to-serial converter; $700 per piano.

(d) Buffer-to-computer interface, including a channel on the computer for drum transfer; $7000 plus $500 per piano.

The hardware configuration for the above interface is shown in Figure 18.

(2) State-Driven Buffered Interface. Using this technique, information would not be stored until something changes at the keyboard. This reduces the amount of storage required, but at

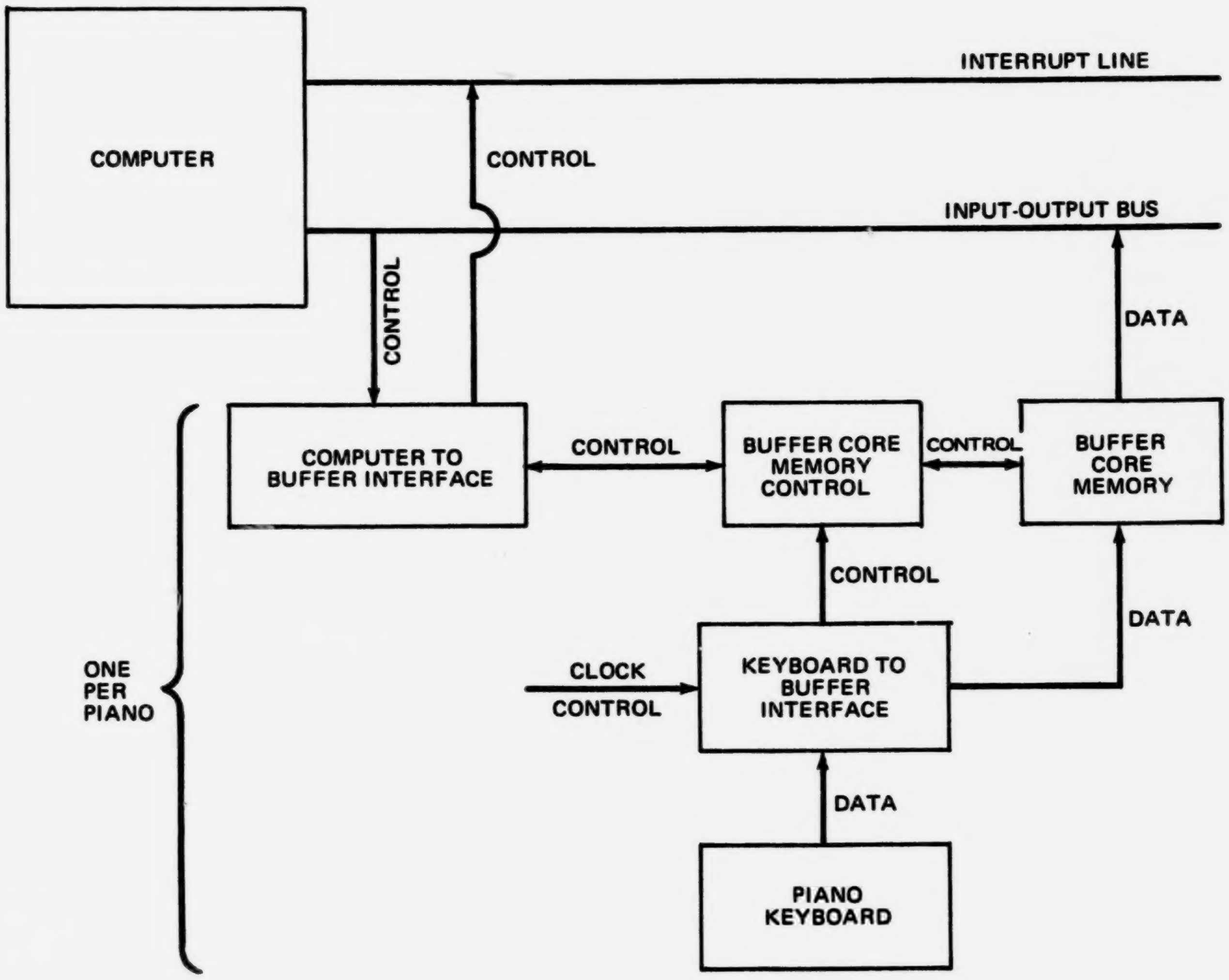

COMPUTER
INTERRUPT LINE
CONTROL
INPUT-OUTPUT BUS
CONTROL
DATA
COMPUTER TO BUFFER INTERFACE
CONTROL
BUFFER CORE MEMORY CONTROL
CONTROL
BUFFER CORE MEMORY
CONTROL
DATA
ONE PER PIANO
CLOCK
CONTROL
KEYBOARD TO BUFFER INTERFACE
DATA
PIANO KEYBOARD

Figure 17. Time-Driven Buffered Keyboard Interface Block Diagram (Technique A)

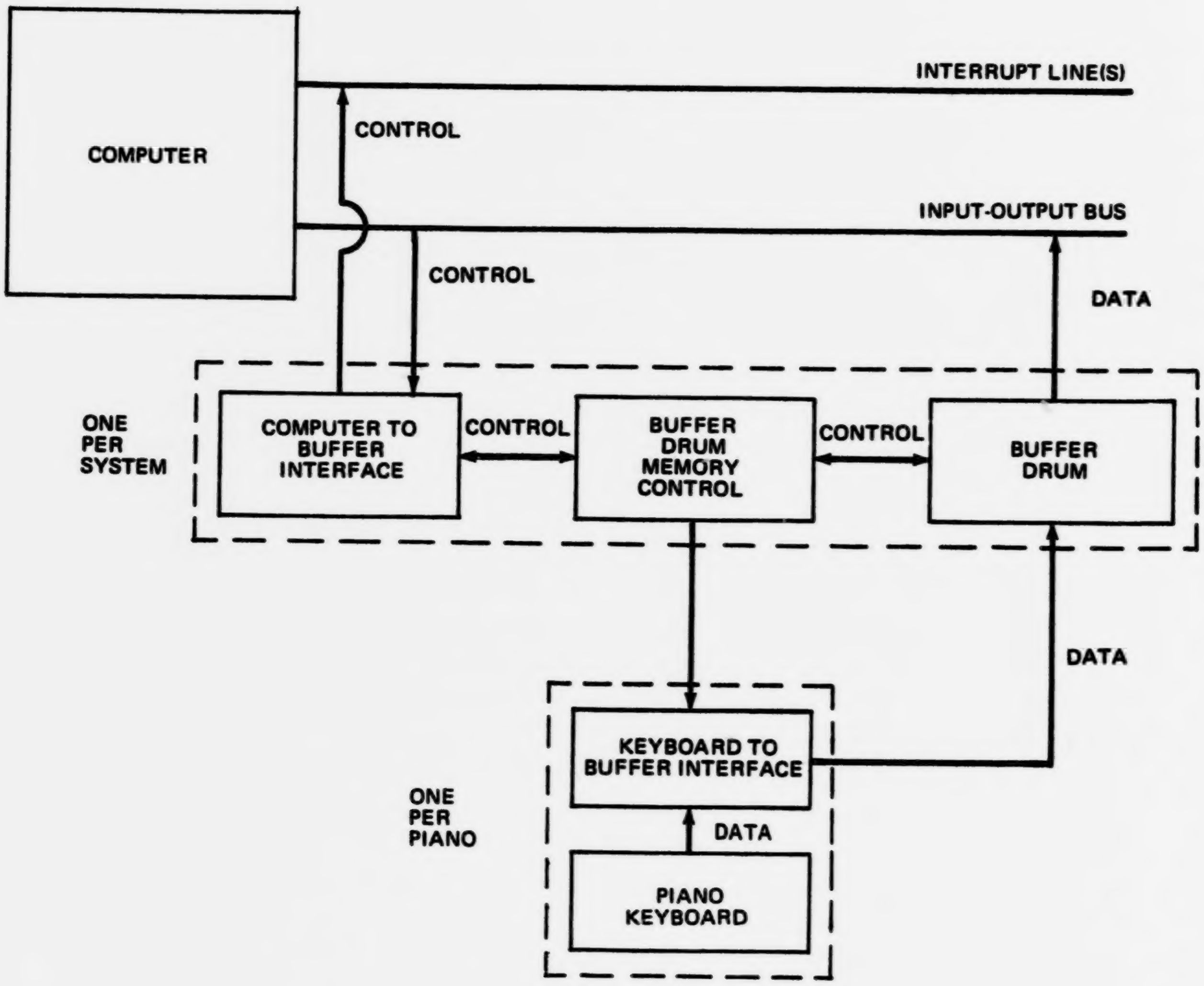

COMPUTER
INTERRUPT LINE(S)
CONTROL
INPUT-OUTPUT BUS
CONTROL
DATA
ONE
PER
SYSTEM
COMPUTER TO BUFFER INTERFACE
CONTROL
BUFFER DRUM MEMORY CONTROL
CONTROL
BUFFER DRUM
DATA
KEYBOARD TO BUFFER INTERFACE
ONE
PER
PIANO
DATA
PIANO KEYBOARD

Figure 18. Time-Driven Buffered Keyboard Interface Block Diagram (Technique B)

the expense of additional logic. Storage can be estimated as follows:

(a) Assume 32 keys per piano.

(b) Assume an average of 4 state changes per second (releasing one key and depressing another can generate 2 state changes).

(c) Timing information (time state change occurs) requires 12 bits.

Allowing 48 bits for state information, a 20-second maximum response duration would require 3840 bits per piano for storage. The following components would be required if the interface is implemented with core memory:

(a) Core memory; $300 per piano.

(b) Core-memory control; $400 per piano.

(c) Keyboard-to-buffer interface; $400 per piano.

(d) State-change sensor; $320 per piano.

(e) Buffer-to-computer interface; $400 per piano.

A synchronous memory would not be appropriate for this technique. The hardware configuration is shown in Figure 19.

G. Task VI: Selection of an Optimum System; Preliminary Report

A purely on-paper selection of an optimum system from the three alternatives defined in Task V was considered prejudicial to the overall results of the study. Consequently, SDC decided to conduct feasibility testing (see Task VII below) for all three design alternatives and to defer conclusions and recommendations until that work was completed. However, an Interim Report summarizing the findings of Tasks I through V was prepared in September, 1969.

H. Task VII: Feasibility Testing of Design Alternatives

Feasibility testing was conducted in the Kellogg Elementary School, Wichita, Kansas. Fifty students (mostly third-grade) participated in the testing, which was conducted during December 1969 and January 1970. The objective was to determine the feasibility, desirability, and effectiveness of each system alternative.

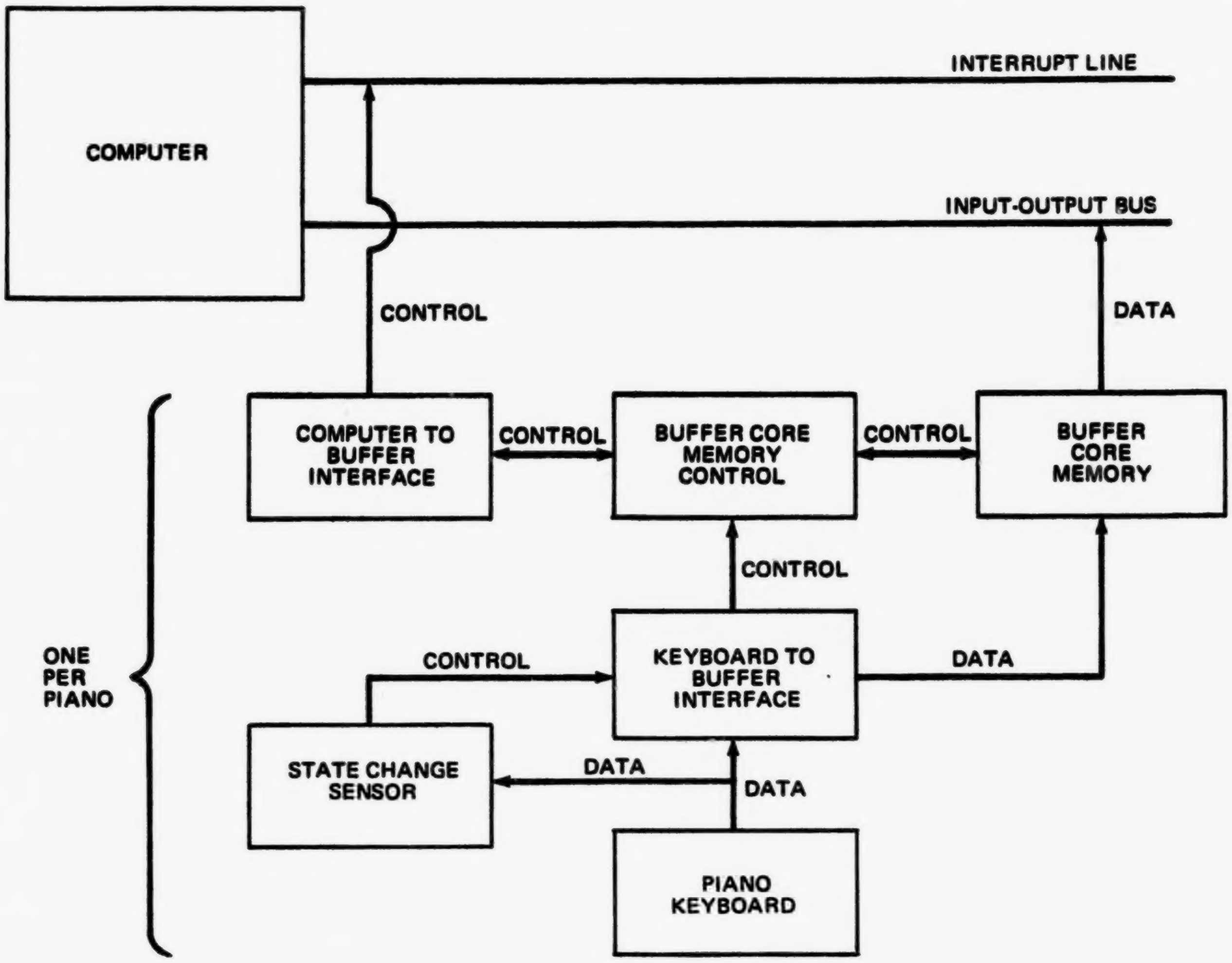

COMPUTER
INTERRUPT LINE
INPUT-OUTPUT BUS
CONTROL
DATA
COMPUTER TO BUFFER INTERFACE
CONTROL
BUFFER CORE MEMORY CONTROL
CONTROL
BUFFER CORE MEMORY
CONTROL
ONE PER PIANO
CONTROL
KEYBOARD TO BUFFER INTERFACE
DATA
STATE CHANGE SENSOR
DATA
DATA
PIANO KEYBOARD

Figure 19. State-Driven Keyboard Buffered Interface Block Diagram

Under the provisions of the study contract, no equipment could be purchased. However, to make the testing as realistic and productive as possible, a variety of equipment was borrowed or leased. The Wurlitzer Company furnished two electronic piano configurations at no charge; each configuration included one teacher's console and eight student pianos. SDC leased or furnished cassette recorders, Videosonic synchronized audio-visual machines, and a teletype terminal. The teletype terminal was connected, through an acoustic coupler, to SDC's computer facility in Falls Church, Virginia. Response panels, operated under pushbutton control, were constructed in-house by SDC. The Wichita public schools furnished a classroom, electrical power facilities, and office equipment.

Lesson materials required for testing were developed and produced by SDC. These consisted of pretest and posttest cards, lesson scripts, hard-copy visuals, 35-mm slide visuals, and cassette tapes on which were recorded lessons and tests in the form of voice narrations and piano music models. These were duplicated in sufficient quantities to permit individualized instruction. The materials, in general, were based on lessons used in the Wichita keyboard experience program. No attempt was made to create innovative materials or to pretest lessons, since the objective was system feasibility testing, not development of instructional materials.

Data were gathered in the form of anecdotal records, teacher and simulator comments, and test scores.

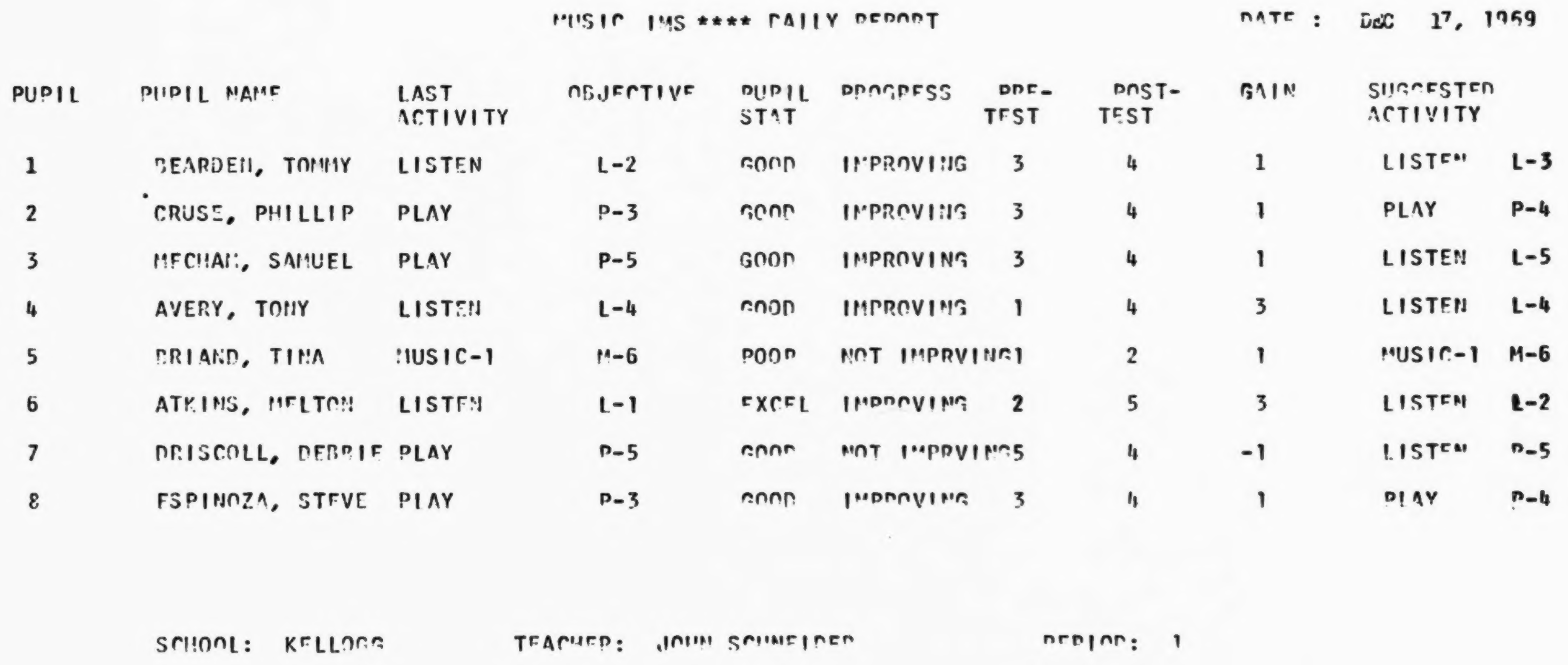
1. Instructional Management System (IMS) Testing. Cassette recorders and lesson tapes were provided to each student. Orientation was conducted by one of the present keyboard experience teachers in Wichita. Pretests and posttests were formatted on IBM cards; instructions for taking the tests were included on the lesson tapes. Each lesson tape was devoted to one or two areas of music concept learning and lasted (including the pretest and posttest) between 20-30 minutes. The class sessions were supervised and monitored by the keyboard experience teacher, who also made subjective judgments as to the performance of each student. The teacher in some cases conducted "live" lessons, rather than using lessons on cassettes. Both modes of instruction are appropriate in IMS.

The teletype terminal was used on a limited basis to read in test scores to a general-purpose data management program operated in SDC's Falls Church computer facility. Printouts were obtained back from the computer; these printouts summarized the scores and prescribed the next recommended activity for each student. Since no computer program has been developed for a music instructional management system, the teletype terminal and computer were principally used for demonstration purposes to show the nature of the diagnostic and prescriptive printouts that can be obtained from an operational system (SDC has developed and operated such a system in public schools in Los Angeles, California). All test scores were also manually recorded, together with the keyboard experience teacher's subjective ratings. Figure 20 shows a sample MUSIC-IMS printout.

Examples of the pretest and posttest cards and outlines of the lesson materials used are given in Figures 21 and 22. The actual narration and music is on cassette tape; consequently, it is not available for inclusion in this report. Each pretest and posttest consisted of five questions; some of the questions were verbal, while others involved listening to prerecorded music.

2. MUSIC-MAN Testing. This system was tested concurrently with the instructional management system and the same instructional materials were used. The significant difference was the employment of simulators to operate the response panels that are part of the MUSIC-MAN configuration. Each simulator was able to hear, in his headset, the lesson materials presented to a student and the student's keyboard responses. This was done on a one-to-one basis--one simulator per student. In simulating a computer, the simulator pressed buttons to light up appropriate labeled displays on the student's response panel: LISTEN, PLAY, TRY AGAIN, GOOD, and WRONG. Pretests and posttests were administered in the same manner as was done for the instructional management system. The simulators were music education students from Wichita State University. On the basis of posttest scores and subjective evaluations of student performance, the simulators determined whether a lesson should be repeated or whether the student should continue to the next lesson. This scheme was obviously limited, since there were insufficient lesson materials to provide branching to remedial lessons. As in the instructional management system, the test scores were transmitted by teletype to the Falls Church computer facility and diagnostic and prescriptive printouts obtained on a sample basis. All pretest and posttest scores were also manually recorded, together with subjective ratings.

3. Advanced CAI System Testing. In testing the first two systems, the keyboard experience teacher noted that the materials used were not always well paced on the cassette tapes and that the content, in some cases, was misleading to the students. Since it was necessary to prepare and record the lesson material



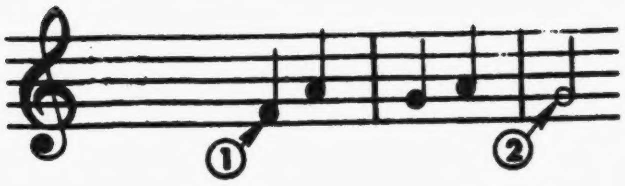
```
                        MUSIC IMS **** DAILY REPORT                   DATE :  DEC  17, 1969

PUPIL    PUPIL NAME       LAST       OBJECTIVE   PUPIL  PROGRESS    PRE-   POST-   GAIN     SUGGESTED
                          ACTIVITY               STAT               TEST   TEST             ACTIVITY

  1       BEARDEN, TOMMY  LISTEN       L-2       GOOD   IMPROVING    3      4       1        LISTEN   L-3
  2       CRUSE, PHILLIP  PLAY         P-3       GOOD   IMPROVING    3      4       1        PLAY     P-4
  3       MECHAM, SAMUEL  PLAY         P-5       GOOD   IMPROVING    3      4       1        LISTEN   L-5
  4       AVERY, TONY     LISTEN       L-4       GOOD   IMPROVING    1      4       3        LISTEN   L-4
  5       BRIAND, TINA    MUSIC-1      M-6       POOR   NOT IMPRVING1       2       1        MUSIC-1  M-6
  6       ATKINS, MELTON  LISTEN       L-1       EXCEL  IMPROVING    2      5       3        LISTEN   L-2
  7       DRISCOLL, DEBBIE PLAY        P-5       GOOD   NOT IMPRVING5       4      -1        LISTEN   P-5
  8       ESPINOZA, STEVE PLAY         P-3       GOOD   IMPROVING    3      4       1        PLAY     P-4


          SCHOOL:  KELLOGG        TEACHER:  JOHN SCHNEIDER             PERIOD:  1
```

Figure 20. Sample Computer Printout



YES NO

① This is a quarter note. ☐ ☐

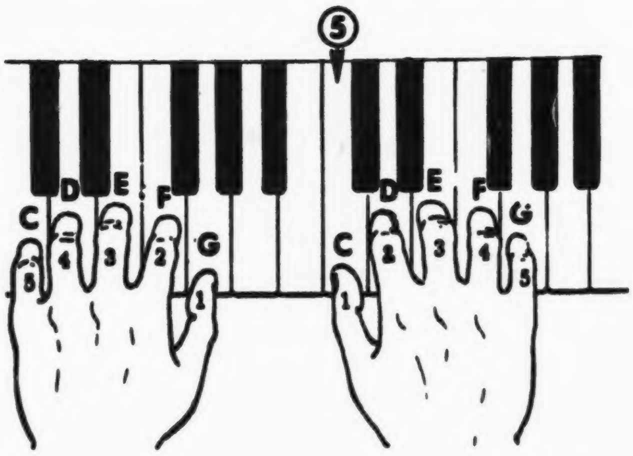
② This is a half note. ☐ ☐

3. A half note gets 2 counts. ☐ ☐

4. A quarter note gets 1 count. ☐ ☐

5. "This Old Man" has quarter notes and half notes. ☐ ☐

Pupil No.______ Pre 5



YES NO

1. The thumb is finger number 1. ☐ ☐

2. There are 4 C's on your keyboard. ☐ ☐

3. From one "C" to the next is one octave. ☐ ☐

4. The musical alphabet starts with A and ends with G. ☐ ☐

5. This is middle C. ☐ ☐

Pupil No.______ Post 2

Figure 21. Sample Pretest and Posttest Cards

IMS AND MUSIC-MAN
OUTLINE OF LESSON 2

1. Pre-test
2. Guessing game song
3. Show slide of numbered fingers; have pupils hold up both hands and count fingers to match the slide.
4. Learn musical alphabet, 7 letters. Start with lowest A and name each white note. A-B-C-D-E-F-G. Have students do this for whole keyboard. From A to A is an octave.
5. Show slide that points out Middle C.
6. Ask pupil to find Middle C and play it.
7. Ask pupil to find and count all C's on the keyboard. (white note before 2-note black groups)
8. Show slide of keys numbered 1-2-3-4-5.
9. Limber fingers by counting and moving 1-2-3-4-5 then 5-4-3-2-1.
10. Starting with thumb on Middle C play 1-2-3-4-5 and 5-4-3-2-1.
11. Now play just 1-2-3 then 3-2-1.
12. Post-test

Figure 22. Sample Lesson Outline for IMS and MUSIC-MAN

separately to test this system (because of the different equipment used), these comments were heeded in designing the new lesson materials. However, the basic content and level of difficulty remained the same. Each lesson module was from 5 to 15 minutes long.

In testing the advanced CAI system, a Videosonic teaching machine was used. This machine has a synchronized audio-visual capability. Audio is recorded on magnetic tape that operates at cassette recorder speed (1-7/8" per second), and visuals are prepared as 35-mm slides. The same response panel used for MUSIC-MAN testing was used in testing the advanced CAI system.

A strong attempt was made to "dehumanize" the Wichita State University students who served as computer simulators. As before, they wore headsets which allowed them to hear the student they were monitoring. Firm instructions were given to forestall their natural tendency to want to help out when a student got into difficulty. The instructions are shown in Figure 23. Lesson scripts were also furnished to the simulators; these closely followed the lessons presented on the Videosonic tapes and contained spaces for scoring. The scripts also contained cues for actuating the response panels. A sample lesson script is shown in Figure 24. No pretests or posttests were given. The criterion for moving a student ahead to the next lesson or repeating a lesson was a score of approximately 75%.

Six lessons were prepared, with the following titles:

(1) Equipment Orientation

(2) High Notes and Low Notes

(3) Black Keys and White Keys

(4) Numbering Your Fingers

(5) Beginning Finger Positions

(6) The Music Alphabet

In lessons 4, 5, and 6, pupils learned to play Hot Cross Buns and Merrily We Roll Along.

Instructions for Simulators

1. Your main role is to simulate the automatic actions of a computer. In this role, you cannot speak, move, point, smile, or frown. All you can do is to press buttons controlling red lights, keep track of pupil progress, and control the lesson by starting it, stopping it, or repeating it.

2. Your secondary role is to simulate a human teacher--but only after it becomes probable that the "computer-controlled" lesson can not get across to the pupil, even with repetition. You should spend as little time as possible in this role. Generally, do not try to help the pupil at all on the first time through a lesson. Let him go all the way through; then repeat the lesson. If he makes better progress the second time through, you will probably not need to help him. If necessary, repeat the lesson a third time. Help him only if he continues to make little or no progress. And then help him only to the extent of getting him to follow the prepared lesson. Do not try to substitute a lesson of your own for the prepared lesson.

3. You also have a third role--to help us evaluate our methods and materials. The last few minutes of each session will be reserved for you to discuss with your pupil what he learned and what he had difficulty with. Do not try to do any teaching during these last minutes. Just try to gather information about what worked and what didn't work during the session. Write your observations and recommendations in the "Comments" spaces at the ends of the appropriate lessons.

4. Red lights. Generally, use the lights only briefly rather than continuously. Flash LISTEN or PLAY only once or twice, when the pupil is to start listening or playing. If the pupil does not respond, try flashing the appropriate light on and off a number of times to attract his attention. The meanings of the lights are:

   LISTEN - Listen; do not play.

   PLAY - Play as instructed.

Figure 23. Instructions to Simulators (Sheet 1 of 3)

GOOD - Trying or satisfactory.

WRONG - Use when pupil needs to have an error pointed out. Do not use first time through a lesson.

PLAY AGAIN - Play what you just tried, again from the beginning.

Use the GOOD light often, to reward any kind of progress (such as trying). GOOD does not mean perfect, but is a sign to the pupil that he should keep going and that the friendly computer has confidence in him.

5. Repeating lessons. In these trial simulations, we have no specially prepared remedial materials. All we can do is to have pupils repeat lessons from the beginning. You, as computer simulator, can stop any lesson at any time and rewind to the lesson's beginning.

Each lesson is 5 to 10 minutes in length. Between lessons the tape contains a short period of silence, ending with a "countdown". The fast rewind rate covers five minutes in about 15 seconds. Rewind to silence or to the "countdown", and advance. You will also have to adjust the positions of the slides appropriately. Tell the pupil, as if you were a recorded message, "Now we're going to try lesson _____ over again from the beginning. See how well you can do this time."

Usually, you should let the pupil go all the way through a lesson before rewinding it. But if he is making no progress at all the second time through, you should stop, rewind to the beginning, and help him in your teacher role. Help him just enough so that he can start learning from the recorded lesson.

6. Scoring. Score the pupil 0, 1, or 2 in each space provided in your lesson scripts. The scores mean:

0 - no response
1 - unsatisfactory response
2 - satisfactory response

Figure 23. Instructions to Simulators (Sheet 2 of 3)

To encourage the pupil, flash the GOOD light for a score of either 1 or 2. A "satisfactory response" (score 2) should indicate that the pupil did what was asked, about as well as could be expected. An "unsatisfactory response" (score 1) indicates that the pupil tried to respond, but performed incorrectly.

At the end of each lesson, tally and total scores to determine whether or not the lesson should be repeated.

7. Videosonic controls. Before you start a lesson, you should have learned how to turn the Videosonic off and on, how to rewind to a lesson beginning, and how to reposition slides. In case of difficulty, ask for help. When the Videosonic is not in use, it should be turned off.

Figure 23. Instructions to Simulators (Sheet 3 of 3)

Lesson 4. Numbering Your Fingers

(Simulator takes actions indicated in brackets. Score 0 for no pupil response, 1 for trying, and 2 for O.K. For 1 or 2, flash GOOD.)

Pupil: ____________________

Date: ____________________

Time: ____________________

Simulator: ________________

Pupil's Previous
Scores on
Lesson 4: ________________

TAPE: Countdown for lesson 4.

SLIDE: Hello, etc.

[LISTEN]

TAPE: Hello, etc. When you're ready to begin, push button A on the picture machine. [LIGHT and SCORE: _____. Help if necessary.]

SLIDE: NUMBERING YOUR FINGERS.

TAPE: [LISTEN]. The picture on the Videosonic machine shows you how to number your fingers to learn to play on the keyboard. Maybe you already know the numbering, but let's make sure. First, put your right hand on some white keys on the right side of the keyboard--the side where the high notes are played. Now I want you to push down your fingers and play the white keys to make a sound like this (_____). [PLAY]. Go ahead, push down the white keys with the fingers of your right hand. [LIGHT and SCORE: _____]. Try that once more. [PLAY]. Go ahead. [LIGHT and SCORE: _____].

[LISTEN]. Next, put the fingers of your left hand on some white keys at the left or low end of the keyboard. Push your fingers down to play the keys. [PLAY]. Go ahead. [LIGHT and SCORE: _____]. Did your notes sound something like this (_____)?

Figure 24. Advanced CAI System Sample Script (Sheet 1 of 4)

Lesson 4, Page 2.

TAPE: Now try pushing down white keys with both hands. [PLAY] Go ahead. [LIGHT and SCORE: _____].

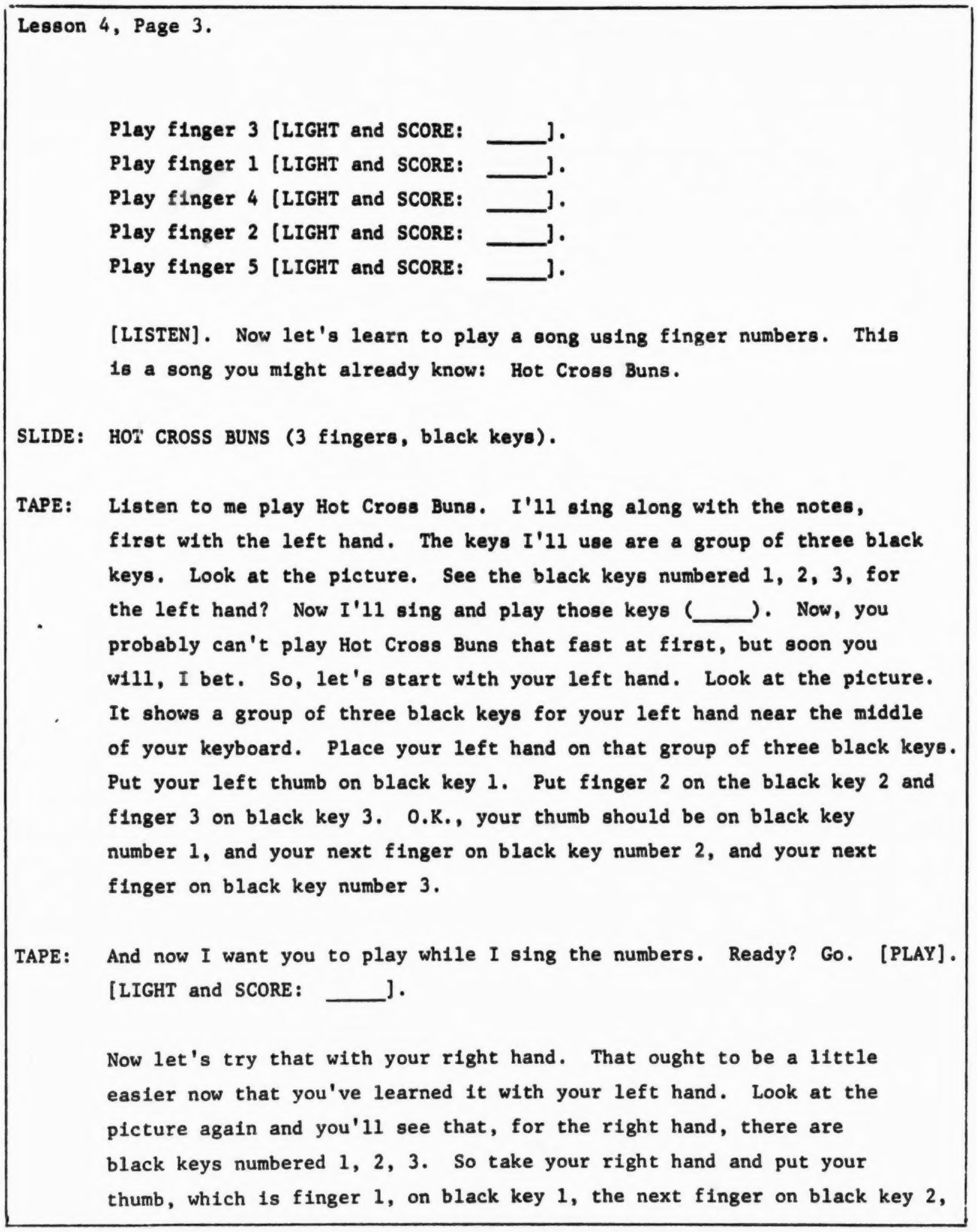
O.K., look at the picture again--notice that each finger of your right hand is numbered 1, 2, 3, 4, and 5, starting with your thumb as finger 1. Place the fingers of your right hand on some white keys. Go ahead, I'll wait for you. All set? [PLAY]. Now play a key with finger 1--your thumb. [LIGHT and SCORE: _____].
Now play a key with finger number 2 [LIGHT and SCORE: _____].
Now play a key with finger number 3 [LIGHT and SCORE: _____].
Now play a key with finger number 4 [LIGHT and SCORE: _____].
Now play a key with finger number 5 [LIGHT and SCORE: _____].
Very good.

[LISTEN]. Now let's play a game. I'll call out a finger number on your right hand and you play a key with that finger. You should have the fingers of your right hand resting on white keys. Ready? Here we go. [PLAY]. Play finger 1. Play finger 5. Play finger 3. Play finger 4. Play finger 5. [LIGHT BUT DO NOT SCORE YET.]

Once more. Play finger 3 [LIGHT and SCORE: _____].
Play finger 4 [LIGHT and SCORE: _____].
Play finger 5 [LIGHT and SCORE: _____].
Play finger 2 [LIGHT and SCORE: _____].
Play finger 1 [LIGHT and SCORE: _____].

TAPE: [LISTEN]. Now look at the left hand in the picture. The thumb is finger 1, the next finger is number 2, all the way to your little finger, which is number 5. Put your left hand on white keys on the left side of the keyboard. Go ahead. All set? Remember, your thumb is finger 1. Here we go. [PLAY]. Play finger 1. Play finger 2. Play finger 3. Play finger 4. Play finger 5. Once more--this time I'll mix up the numbers. Here we go. [PLAY].

Figure 24. Advanced CAI System Sample Script (Sheet 2 of 4)



Lesson 4, Page 3.

Play finger 3 [LIGHT and SCORE: _____].
Play finger 1 [LIGHT and SCORE: _____].
Play finger 4 [LIGHT and SCORE: _____].
Play finger 2 [LIGHT and SCORE: _____].
Play finger 5 [LIGHT and SCORE: _____].

[LISTEN]. Now let's learn to play a song using finger numbers. This is a song you might already know: Hot Cross Buns.

SLIDE: HOT CROSS BUNS (3 fingers, black keys).

TAPE: Listen to me play Hot Cross Buns. I'll sing along with the notes, first with the left hand. The keys I'll use are a group of three black keys. Look at the picture. See the black keys numbered 1, 2, 3, for the left hand? Now I'll sing and play those keys (_____). Now, you probably can't play Hot Cross Buns that fast at first, but soon you will, I bet. So, let's start with your left hand. Look at the picture. It shows a group of three black keys for your left hand near the middle of your keyboard. Place your left hand on that group of three black keys. Put your left thumb on black key 1. Put finger 2 on the black key 2 and finger 3 on black key 3. O.K., your thumb should be on black key number 1, and your next finger on black key number 2, and your next finger on black key number 3.

TAPE: And now I want you to play while I sing the numbers. Ready? Go. [PLAY]. [LIGHT and SCORE: _____].

Now let's try that with your right hand. That ought to be a little easier now that you've learned it with your left hand. Look at the picture again and you'll see that, for the right hand, there are black keys numbered 1, 2, 3. So take your right hand and put your thumb, which is finger 1, on black key 1, the next finger on black key 2,

Figure 24. Advanced CAI System Sample Script (Sheet 3 of 4)

Lesson 4, Page 4.

and the next finger on black key 3. All set? O.K., now play Hot Cross Buns with your right hand and I'll sing along with you. Here we go. [PLAY]. (_____). [LIGHT and SCORE: _____]. Try that once more. Ready? Play. [PLAY]. (_____). [LIGHT and SCORE: _____].

Don't worry if you can't play Hot Cross Buns with either hand. You'll get a chance to practice and try again.

[TURN OFF VIDEOSONIC MACHINE].

[Tally of Scores: _____0's, _____1's, _____2's. Total Points = _____ out of 46 possible. If total is 34 or more, go on to next lesson. Otherwise, give pupil "repeat" message, rewind tape, and reposition slides. Start again with new score sheet.]

[COMMENTS BY SIMULATOR:

]

Figure 24. Advanced CAI System Sample Script (Sheet 4 of 4)

4. Discussion of Test Results. Presented here are the raw quantified data and subjective data gathered during feasibility testing. These data are hardly conclusive because of the short test period, the small sample of students, and the fact that the systems tested exist largely on paper. Conclusive evidence can only be obtained by building and operating the systems over an extended period of time; this was obviously beyond the scope of the study.

Nevertheless, the results were extremely encouraging and indicated that all systems are educationally and technologically feasible. Time and again, it was observed that the children participating in the testing learned quickly through the combined media of a piano, headset, pre-recorded audio, visuals, and response panels. The principal occasions for human intervention stemmed not from the students' inherent ability and interest in grasping the material presented, but from ambiguities, faulty pacing, and other deficiencies in the lesson and test material. This was to be expected because the study focused on feasibility, not the development of empirically tested lessons. Progress would have been greatly enhanced with better materials.

Especially noteworthy was the almost complete lack of correlation between the students' keyboard performance and their performance in the Iowa Test of Basic Skills (ITBS). The ITBS composite percentile rating of each student was obtained from the Kellogg elementary school (these data were unavailable for students who had recently transferred to the school). As a group, students with low ITBS ratings performed about as well as students with high ITBS ratings. This was not due to presenting "oversimplified" material--the material used was equivalent to that used in the regular Wichita keyboard experience classes. Further, only three students had previous exposure to piano lessons.

The rate of progress was judged by the keyboard experience teachers present, and by SDC personnel who had observed the present Wichita keyboard experience program, to be much faster than in the present program. Again, this judgment will have to be supported by longer-term testing of an experimental system. The principal reservation expressed by one keyboard experience teacher is a teacher's ability to use the instructional management system (IMS) in a large class; he believes it would be difficult with more than eight students. Other criticisms expressed concerned the lesson materials themselves; in general, the pretests and posttests were delivered (on tape) too slowly, which led to student impatience, and there was a lack of balance between having students listen and perform--more performance would have been better (this was partly rectified in the testing of the advanced CAI system).

Typical student comments were:

> "When are we going to learn to play a song?"
>
> "I want to put my answer down because I already know it." (Comment concerning the slow pacing of the pretest and posttest presentation).
>
> "How come we have to quit so soon? Why don't you make it (the lesson) an hour?"

The students adjusted rapidly to observing lights on their response panel and to following instructions to push buttons on their Videosonic machine to advance to the next lesson segment.

It was clear that the computer programming of an operational system will have to be very flexible and ingenious to cope with the problem of "what is a correct response?" The computer program can detect what specific keys are depressed and the time sequence. But if only two notes out of a three-note chord are played, should it be judged correct? Or, if a student plays an octave higher or lower than asked to, because of keyboard disorientation, should this be judged incorrect? Finally, although the computer program can tell what keys were depressed, it cannot tell what fingers were used to depress the keys. However, this is in the area of piano fingering technique, which is not of major concern to keyboard experience.

The raw scores recorded for all students participating in the testing are given in Tables 5 through 10. The lessons given in IMS and MUSIC-MAN were longer than those given in the advanced CAI system; consequently, more lessons were covered in the advanced CAI system. Also, an unscored orientation lesson was presented for all three systems. Some students, inevitably, were absent one or more days. And, on one occasion, some students were inadvertently given a "repeat" lesson, even though they scored high on the previous lesson.

Table 5. Instructional Management System Test Scores (Period 1)

Pupil No.	ITBS Score	Lesson 1				Lesson 2				Lesson 3			
		Pre	Post	Gain	Rating	Pre	Post	Gain	Rating	Pre	Post	Gain	Rating
1	44	5	5	0	4	4	4	0	3	3 4	4 4	1 0	1 3
2	07	2 3	3 4	1 1	2 1	2 1	1 4	-1 3	2 1				
3	NA	4	5	1	3	4 4 4	5 3 5	1 -1 1	2 1 1				
4	65	3	4	1	2	3 4	2 4	-1 0	3 3				
5	80	3	3	0	4	5	5	0	3	3	4	1	3
6	62	2	4	2	4	4	4	0	3	3 4	4 4	1 0	3 4
7	62	3	4	1	1	4	4	0	2	3 4	4 4	1 0	1 3
8	31	5 4	2 3	-3 -1	2 4	4	2	-2	2				

Pre = Pretest (0-5)

Post = Posttest (0-5)

Rating = Teacher's subjective rating (0-4)

NA = Not available

NOTE: Multiple entries for a lesson indicate that the student repeated the lesson.

Table 6. Instructional Management System Test Scores (Period 2)

Pupil No.	ITBS Score	Lesson 1				Lesson 2				Lesson 3			
		Pre	Post	Gain	Rating	Pre	Post	Gain	Rating	Pre	Post	Gain	Rating
09	22	3	4	1	1	3	5	2	2	1	1	0	1
										3	1	-2	1
10	83	5	5	0	4								
		3	4	1	3								
11	48	4	4	0	3	3	5	2	2	0	3	3	3
										4	4	0	4
12	88	3	5	2	4	3	5	2	4	2	4	2	3
		5	5	0	4								
13	72	4	4	0	4	3	4	1	2	2	3	1	3
										3	3	0	3
14	97	5	5	0	4	2	5	3	3	3	3	0	4
		5	5	0	4								
15	88	5	5	0	2	4	5	1	3	3	3	0	3
		5	5	0	4								
16	75	4	5	1	3	3	4	1	3	3	3	0	3
		5	5	0	4								

Table 7. Instructional Management System Test Scores (Period 3)

Pupil No.	ITBS Score	Lesson 1				Lesson 2				Lesson 3			
		Pre	Post	Gain	Rating	Pre	Post	Gain	Rating	Pre	Post	Gain	Rating
17	22	4	5	1	4	4	5	1	3	4 2	3 3	-1 1	3 1
18	22	3	3	0	3	3	4	1	3	4 0	3 3	-1 3	2 2
19	03	2	5	3	2	3	4	1	2	2 2	3 1	1 -1	2 1
20	44	3	5	2	3	4	5	1	3	2 2	2 1	1 -1	3 3
21	48	4	5	1	4	3	5	2	2	3 4	2 2	-1 -2	3 3
22	NA	2	2	0	4	4	4	0	3	3 3	3 3	0 0	3 2
23	56	4	5	1	4	4	5	1	4	3 1	4 4	1 3	3 2
24	NA	2	5	3	3	4	4	0	3	3 3	2 4	1 1	2 1

Table 8. MUSIC-MAN Test Scores

Pupil No.	ITBS Score	Lesson 1				Lesson 2				Lesson 3				Lesson 4			
		Pre	Post	Gain	Rating	Pre	Post	Gain	Rating	Pre	Post	Gain	Rating	Pre	Post	Gain	Rating
25	09	2 2	4 4	2 2	1 1	3 4	1 2	-2 -2	1 3								
26	NA	2 5	1 5	-1 0	4 2												
27	31	2	5	3	3												
28	02	3	4	1	4	4	5	1	3	2	3	1	4				
29	48	1 4	5 5	4 1	3 3	4	5	1	3	3	3	3	3	3	4	1	4
30	54	4	4	0	4	3 2	3 0	0 -2	3 3								
31	92	5	4	-1	4	4	4	0	4	2	4	2	4	3	5	2	4
32	63	3	2	-1	3	3	5	2	4	2	4	2	4	5	2	-3	4

Pre = Pretest (0-5) Post = Posttest (0-5) Rating = Teacher's subjective rating (0-4) NA = Not available

NOTE: Multiple entries for a lesson indicate that the student repeated the lesson.

Table 9. MUSIC-MAN Test Scores (Continued)

Pupil No.	ITBS Score	Lesson 1				Lesson 2				Lesson 3				Lesson 4			
		Pre	Post	Gain	Rating	Pre	Post	Gain	Rating	Pre	Post	Gain	Rating	Pre	Post	Gain	Rating
33	75	5	5	0	3	4	5	1	3	4 2	4 3	0 1	2 2	3	3	0	4
34	78	4	5	1	3	4	4	0	2	2 4	4 4	2 0	3 3				
35	80	2	4	2	3	3	3	0	3	2 2	3 2	2 0	3 3				
36	36	4	3	-1	2	4	5	1	3	3 1	2 3	-1 2	2 4				

Table 10. **Advanced CAI System Test Scores**

Pupil No.	ITBS Score	Lesson 1 (Not Scored)	Lesson 2 (Max = 38)	Lesson 3 (Max = 36)	Lesson 4 (Max = 46)	Lesson 5 (Max = 22)	Lesson 6 (Max = 28)
37	52		36	33	42	16-15-17	23
38	95		35	35	46	18	27
39	NA		35	36	45	15-19	
40	72		28	27	37-42	10-14I	
41	NA		35	33	33-36	Absent 1 day	
42	07		36	35	46	15-15	
43	01		32	24	27-39	Absent 1 day	
44	22		34	34	38-41	15	
45	22		36	31	39-42	15-11I	
46	17		36	35	26-38	Absent 1 day	
47	13		31	32	33-34		15
48	NA	This student was absent for all sessions					
49*	NA		36	35	39	15-19	22
50*	29		36	36	46	19	20
51*	32		38	36	44	14-17	23

*Not originally scheduled to participate; indicated by school to have behavioral problems.

I = Lesson not completed because of time.

NOTE: Multiple entries indicate that the lesson was repeated.

III. COSTS AND ADVANTAGES OF ALTERNATIVE SYSTEMS

A. Scope

This chapter contains cost-benefit comparisons of the present Wichita keyboard experience program, of three computer-based systems subjected to feasibility testing, and of an alternative non-computer-based system. A final section is devoted to electronic piano cost considerations.

One-time costs of materials and equipment are commonly distributed over a period representative of their expected useful life. Electronic pianos, for example, have average life expectancies comparable to those of conventional pianos--10 years to a lifetime. Similarly, soundly conceived lesson materials in fundamental music concepts can be expected to have a long useful life. However, a period of three years (36 months) is commonly used in school accounting offices to amortize the cost of one-time expenditures and has been adopted for this study.[1] Consequently, it is important to bear in mind that the costs presented in this chapter are for the first three years of operation; the costs in succeeding years would be reduced.

Equipment maintenance costs are not given in this study. For computer and computer-related equipment, maintenance rates and contracts vary among hardware manufacturers. One form of maintenance policy establishes a monthly maintenance rate, which covers the cost of periodic equipment checks and the repair of any equipment breakdown. These monthly rates seem to average around one per cent of the purchase price. Other vendors offer maintenance agreements based on a fixed price for each type of repair, and promise service within a certain number of hours. As noted elsewhere in this report, maintenance requirements for electronic pianos are minimal.

The costs and technological assumptions made in this chapter may become obsolete in a relatively short period of time. The field of computer machinery is in a state of rapid change, and to assume that change will not continue would be a serious error. Overall, the costs of computers and related equipment are trending downward rather sharply. In 1967, Thomas J. Watson, chairman of International Business Machines, prophesied that the computer will be one to five per cent of its present price in a decade.[1] We have no basis for either confirming or refuting that statement except to reiterate that the costs are going down. This is in contrast to everrising expenditures for teacher salaries--the largest item in an educational budget.

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[1] The Wichita Public School System, however, uses a five-year amortization period for textbooks and for equipment that has a life expectancy of over five years.

A bonafide system cost is the cost to the user. In an educational system, the users are students. Their investment is their own time--a most critical resource. The effectiveness of an educational system must be partly measured in the time expended by students to acquire knowledge. This study is one of many attempts to assure that students get the best possible dividends from their investment.

B. Wichita Keyboard Experience Program

For this feasibility study, the Wichita keyboard experience program is regarded as the baseline system against which other possible systems are to be compared. The program and its results have been described in Chapter II, Section C. The information that follows is therefore confined to a cost analysis.

Table 11 presents cost data for the program, as furnished by the school administration. The transportation costs are for once-a-day movement of the two vans. These cost data have been used as a base from which to extrapolate the costs of implementing the same program for all third-graders in the Wichita elementary school system on a twice-a-week schedule. To provide a standard basis of comparison of the costs of the program with those of the other system configurations documented in this report, we have adjusted the raw data furnished by the school administration and eliminated some of the special factors operative in the program. For example, two schools are in close proximity and students from the two schools can attend keyboard experience classes without moving the van. Also, most of the schools in the program do not have enough third-grade students to fill up the available time during a normal school day; consequently, students from other grades are accommodated to maximize utilization of the teachers and the vans. Finally, current equipment costs would be substantially more than those shown in Table 11.

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[1] The Computer in Education, Institute for Development of Educational Activities, Inc., Dayton, Ohio, 1970, p. 17.

Table 11. Keyboard Experience Program Costs

Initial Investment	Unit I (1966)	Unit II (1967)
Trailer unit complete with connecting cables, lighting, heating, air conditioning, steps, electrical outlets and blackboard	$ 5,900.00	$ 6,000.00
Equipment to be added to trailer		
Blinkers and wiring for same	91.88	91.88
Two fire extinguishers @ $25.00 each	50.00	50.00
Six leveling jacks and installation	33.00	33.00
Cost of electrical equipment at school sites, Outlets with meters and locked switch boxes, installed, at $150.00 each	900.00	750.00
Teaching equipment		
Teachers piano	300.00	300.00
Student pianos: Unit I, 23 electric pianos and benches @ $300.00 each; Unit II, 22 electric pianos and benches @ $320.62 each	6,900.00	7,053.64
Communications center	263.50	297.50
Cables: Unit I, 4 @ $63.00 each; Unit II, 3 @ $66.67	252.00	200.01
Installation of pianos, labor	70.72	70.72
Installations of communications system	80.00	80.00
Wallensack 60 tape recorder	82.00	82.00
Overhead projector		100.00
Trailer hauler and pickup are available through the Board of Education garage	No cost	No cost
Total Initial Investment	$14,923.10	$15,108.75
Operating Expenses		
Teachers	*	*
Cost of labor for moving units per year	$ 4,050.00	$ 4,050.00
Estimated cost of electrical power per year	288.00	288.00
Total Operating Expenses (less teacher's salary)	$ 4,338.00	$ 4,338.00

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* Individual salaries are confidential; the minimum salary in effect, in Wichita Public Schools, for FY 1968-1969 was $5,800; the minimum for 1969-1970 will be $6,200. Estimated keyboard teacher salary is $9,000.

Our cost analysis is based on the following assumptions and approximations, which we believe to be accurate within 10 per cent:

1. A teacher salary of $9,000 per year.
2. Labor costs of $8,000 per year to move one van twice a day.
3. Twice-a-week instruction (two 30-minute sessions) for each pupil.
4. One hundred elementary schools (at present, Wichita has 91 elementary schools).
5. A total third-grade population of 6,000 (2 third-grade classes per school, each having 30 students). Wichita's current third-grade population is approximately 5,500 students.
6. An average keyboard class size of 15 students (half of a typical third-grade class).
7. A 20 per cent increase in the cost of equipment shown as the "initial investment" in Table 11.

Each teacher and van can serve 5 schools a week on a twice-a-week schedule, provided the vans are moved twice a day. The costs are:

Annual Cost Per Unit (Service 5 Schools)

Teacher's salary.	$ 9,000
Labor to move mobile vans	8,000
Equipment ($18,000 distributed over a 3-year amortization period).	6,000
Electrical power.	300
Miscellaneous (supplies, etc.).	100
Total Per Year	$23,400

To serve all 100 elementary schools, 20 teachers and 20 vans would be required. The total annual cost to implement and operate the existing system, then, would be 20 X $23,400 = $468,000.

For a third-grade population of 6,000 students, the cost per year per student would be $78.00. For 36 hours of instruction (two half-hour sessions per week over the school year), this comes to approximately $2.17 per instruction hour per student. The major cost components in this system are teacher salaries and labor to move the vans. Once the equipment is paid for, annual expenditures would be approximately 70 per cent of those incurred for the first three years.

Undoubtedly some efficiencies could be introduced to lower the above costs. There would be enough slack in the schedule to permit perhaps two more class sessions a day--additional third-grade classes within a given school or classes from other grades. However, some time must be reserved during the day to transport the vans. (Doubling the number of vans and teachers to avoid moving the vans would be more costly than moving the vans.) Overall, it is difficult to see how the costs could be reduced below $60 dollars per student year under the most favorable circumstances (such as fewer, more densely populated schools). Sufficient numbers of pianos cannot be installed in the vans to handle an entire class of 30 students at one time. Also, based on Wichita's experience over the past five years, 30 students might be an insupportable load on a keyboard experience teacher. The assumption made that half a third-grade class (15 students) can be handled at one time seems valid. A compromise between the present cost of $78.00 per pupil year and the more optimistic cost of $60.00 per student year is $72.00 per student year or $2.00 per instruction hour.

C. Instructional Management System (IMS)

This alternative design configuration is described in Chapter II, Section F1. To briefly recapitulate, it is a computer-assisted instructional management system in which a computer functions off-line only; there is no interface between the computer and the electronic pianos, and the computer can be remotely located. The design concept provides for fine-grained testing of student progress at frequent intervals during the course of instruction. Tests are administered via audio-tape recordings of music and voice statements; the students fill out a machine-readable test form. The test forms are then optically scanned for input to the computer. Diagnostic and prescriptive programs are provided to analyze the results and to output prescriptive information for each student. The teacher then uses this prescriptive information as the basis for continuing the learning process on an individualized basis. Thus, the teacher's role is essentially that of a manager of the instruction.

The most obvious advantage of the IMS system, compared to an interactive CAI system, is its cost. As will be detailed later in this section, the cost is well within the reach of a sizable number of school districts. A further advantage is that such systems have already been developed and are being tried out in a number of schools, although none, to our knowledge, have incorporated music as one of the subjects taught under those systems.

IMS is much stronger than CAI in providing school personnel with what may be called decision-oriented information about student progress. IMS displays and reports are specifically designed to help teachers and other school personnel make practical, day-to-day decisions about what to do with individuals or groups of students. Most CAI systems provide little more than a frame-by-frame response history. Some CAI systems do provide statistical summaries of items completed, per cent of errors, etc., but these are generally retrievable only with some effort, and they are presently oriented more toward the researcher than toward the school practitioner.

Another advantage of IMS is that it is perceived by teachers as less of a threat than CAI. Proponents of CAI often reassure teachers that CAI is not intended to replace them, but to free them for higher-level activities that make better use of their training and experience. Nevertheless, it is significant that teachers are felt to need such reassurance. IMS, however, is clearly designed with the teacher as its hub; it is viewed immediately as an aid, not as potential competition. This can greatly ease its introduction into schools.

On the negative side, it is difficult if not impossible for IMS to provide feedback as quickly as CAI, or at as detailed and specific a level. Although some exploratory work has been done by placing a test-scoring device in individual schools, such an approach is only a compromise solution because of queuing problems and other logistical considerations. Student feedback in IMS must still ultimately depend on the teacher, using information given him by the computer, or on knowledge of results that may be provided by the lesson materials themselves. If the school has a good supply of individualized study materials, such as programmed tests, the feedback may compare fairly well with that provided by CAI.

For keyboard experience, the utility of the fine-grained frequent testing characteristic of IMS is highly debatable. It seems unlikely that keyboard experience programs will ever be conducted five days a week--we have projected two half-hour sessions a week as a norm. Intuitively, it seems that testing could be effectively administered at less frequent intervals outside an IMS environment. In keyboard experience, we are dealing with a domain of learning that is largely affective or aesthetic.

To be cost-effective, IMS must serve many subject areas (reading, arithmetic, etc.) from grades K-12. The cost of operating an IMS for only a single grade or class in a school would be very high. Thus, in the costing that follows, it should be borne in mind that keyboard experience is only one of the subjects served by the computer system. The costs are in addition to the costs established for classroom keyboard experience instruction (Chapter III, Section B) and for classroom instruction in other subjects; therefore, the additional costs must be weighed against increased educational effectiveness.

For this study, we estimate that a student will take an average of one IMS assessment test per week for each course in which he is enrolled, and that an IMS course will have 40 tests, on the average. IMS tests may contain an average of 30 items, linked to 5 specific objectives which in turn are linked to 3 general objectives. On the average, 6 items are keyed to each objective tested. Therefore, an IMS-monitored course will have an average of 150 specific objectives, nested under approximately 10 general objectives.

The costing below is predicated on the following assumptions:

1. Four courses of instruction (one of which is keyboard experience), supported from grades K-12.

2. Three "model" school districts: 3800 students, 9800 students, and 58,800 students. In these model school districts, each elementary school has 600 students, each junior high school has 1200 students, and each high school has 2000 students.

The equipment configuration that would be optimum differs with each model school district. The following are approximate equipment costs of representative configurations for each case.

Configurations I and II below are for one elementary school (600 students), one junior high school (1200 students), and one high school (2000 students).

Configuration I

	Elementary School	Junior High School	High School
Equipment cost	$54,000	$64,000	$64,000
Equipment cost amortized over 3-year period	$18,000	$21,300	$21,300
Cost per student per year (4 courses)	$30	$18	$11

The costs for Configuration I are for a dedicated single computer system with directly connected optical scanner and teletypes. All reports are output immediately after the day's tests have been scanned. The difference in equipment costs between the elementary school and the junior and senior high schools is for additional disk storage and an extra terminal.

Configuration II

	Elementary School	Junior High School	High School
Equipment cost	$44,000	$45,000	$45,000
Equipment cost amortized over 3-year period	$14,700	$15,000	$15,000
Cost per student per year (4 courses)	$24.50	$12.50	$7.50

Configuration II provides immediate real-time processing on a single dedicated computer system of an Achievement Report only. Historical and Detail Reports are deliverable on an overnight basis. The difference in equipment costs between the elementary school and the junior and senior high schools is for additional disk storage and an extra terminal.

Configuration III involves a school district of 9800 students composed of 9 elementary schools (600 students each), 2 junior high schools (1200 students each), and 1 senior high school (2000 students). A more powerful computer system is used here, which is shared by the entire school district. The terminals are in the individual schools, and are costed accordingly.

Configuration III

Cost of computer system for school district	$126,000
Cost of computer system amortized over 3-year period	$42,000
Cost per student per year (9800 students)	$4.30

	Elementary School	Junior High School	High School
Terminal costs	$5,000	$6,000	$6,000
Terminal costs amortized over 3-year period	$1,700	$2,000	$2,000
Cost of terminal per student per year	$2.90	$1.70	$1.00
Cost of computer per student per year	$4.30	$4.30	$4.30
Total cost per student per year (4 courses)	$7.20	$6.00	$5.30

Configuration III provides immediate real-time processing of an Achievement Report. Historical and Detail Reports are deliverable on an overnight basis. The differences in terminal costs between the elementary school and junior and senior high school configurations are due to additional Modem and teletype requirements for the latter.

Configuration IV involves a school district of 58,800 students composed of 54 elementary schools (600 students each), 12 junior high schools (1200 students each), and 6 senior high schools (2000 students each). A large-scale computer system is used here, which is shared by the entire school district. The terminals are in the individual schools, and are costed accordingly.

Configuration IV

Cost of computer system for school district	$1,200,000
Cost of computer system amortized over 3-year period	$400,000
Cost per student per year (58,800 students)	$7.00

	Elementary School	Junior High School	High School
Terminal costs	$5,000	$6,000	$6,000
Terminal costs amortized over 3-year period	$1,700	$2,000	$2,000
Cost of terminal per student per year	$2.90	$1.70	$1.00
Cost of computer system per student per year	$7.00	$7.00	$7.00
Total cost per student per year (4 courses)	$9.90	$8.70	$8.00

Configuration IV provides immediate real-time processing of all reports. The differences in terminal costs between the elementary school and junior and senior high school configurations are due to additional Modem and teletype requirements for the later. Although the student cost per year for Configuration IV is higher than that calculated for Configuration III, it is likely that the demands of IMS processing would not require dedication of the computer system in Configuration IV--it would be available for other school data-processing demands.

Although IMS computer programs exist, they exist for specific machines. The estimated cost for converting the programs to any given machine is $30,000. To develop an IMS course for elementary school keyboard experience, formatted for use by IMS programs, would cost an estimated $108,000. These are one-time costs that can be amortized over a 3-year period.

Salaries of personnel needed to operate the various computer systems are not included in the foregoing costs. A minimum of one individual would be needed for each small-scale configuration. Two to four individuals would be needed for the largest configuration.

Configurations III and IV involve the use of small terminals at each school, which teleprocess data to a local central data-processing facility. The charges for the use of telephone lines for low-speed teleprocessing are the same as those for private telephone service. At the terminal, an acoustic coupler connects a standard telephone hand set to the terminal equipment. At the central facility, a data set connects the telephone line to the computer's communication equipment. Data sets can be rented from the telephone company. Rates for low-speed data sets range from $35 to $75 per month.

D. MUSIC-MAN System

This configuration is described in Chapter II, Section F2. Briefly, it is a hybrid system which lies between the IMS system and a sophisticated, highly interactive, CAI system. It has management capabilities analogous to those ascribed to the IMS system; in addition, the electronic pianos are interfaced with a mini-computer to provide a moderate level of direct interaction between individual students and the computer during the course of instruction. For this design alternative, it is conceived that the equipment installation (pianos, computer, and ancillary equipment) can be installed either in a mobile van or in a regular classroom.

The advantage of this system, compared to IMS, is the immediacy of feedback to the students via labeled light displays on a response panel. Computer programs interpret the students' keyboard responses and light the appropriate displays. The computer programs also maintain a record of student responses and prepare off-line diagnostic and prescriptive reports for the teacher.

A significant drawback of this system is the problem of synchronizing the computer programs with the lesson material. To reduce terminal console costs, cassette recorders and hard-copy visuals are employed. Thus, the lesson materials are not under direct computer control. This means that the lesson materials would have to be indexed in computer storage and the index codes entered by the student, via a panel of buttons or similar arrangement, so that the computer knows at all times what lesson module the student is on. Branching must be accomplished through the prescriptive reports generated off-line, or by a signal to the student from the computer program to proceed to lesson X, based on the student's performance on the current lesson.

The cost estimates for MUSIC-MAN are based on the following:

1. One 1-microsecond mini-computer per 16 pianos.
2. Thirty-two keys instrumented per piano.
3. Twelve half-hour blocks of time available during a school day.
4. Two half-hour sessions per student per week.

Based on the above, each configuration of 16 pianos and 1 mini-computer could serve 480 students. To serve 6,000 students (the figure used for implementing the Wichita keyboard experience program in all Wichita elementary schools at the third-grade level), 13 such configurations would be required. The costing below is prorated among 6,000 students:

13 mini-computer systems ($70,000 each)	$910,000
208 instrumented pianos (including switches and associated circuitry for 32 keys, response panels, and index code panels, at $100 each)	$208,000
208 state-change interface modules ($550 each)	$114,400
208 cassette player-recorders ($60 each)	$ 12,480
13 mobile vans ($7000 each)	$ 91,000
Computer program development and production	$100,000
Lesson development and production	$ 60,000
Total	$1,495,880

Amortized over a 3-year period, the above cost is approximately $500,000 annually. This is a per student cost (6,000 students) of $83 per year. For 36 hours of instruction, the cost is approximately $2.30 per student hour. To this must be added the salaries of 13 teachers at $9,000 each, labor to move the vans at $8,000 per van per year (moved twice a day), and electrical power. Maintenance costs are not included. The total estimated cost would be thus in excess of $3.50 per student hour. The preceding calculations are based on maximum efficiency of use of the equipment. If the same basis for costing the Wichita keyboard experience program is used (20 vans and 20 teachers serving only third-grade students in 100 schools), the costs would increase approximately one-third, which would yield a cost of about $4.50 per student hour.

Economies could be effected by judicious location of each configuration in classrooms, rather than using mobile vans, and eliminating the teacher as a full-time participant while the students are at the keyboard consoles.

Nevertheless, because of the heavy IMS component in the system, it is doubtful that the teacher load could be reduced to less than 50 per cent of the load in the present Wichita keyboard experience program.

Overall, the costs, logistics, and feedback and control limitations of this system do not appear to make it a very viable alternative. But the computer program concepts explicated in the design will be of great value in developing a more highly interactive CAI system--one in which feedback is not limited to response panel indicators and in which lesson presentation is under computer control.

E. Advanced CAI System

This system is described in Chapter II, Section F3. Briefly, it is a sophisticated CAI system in which a number of mini-computers would control the interfaces between electronic piano terminals and a large-scale computer; the large-scale computer would perform the instructional processing. A highly interactive programming language would be used to provide a truly individualized, student-centered, learning environment. The main computer can be remotely located and serve a number of classes at once on a time-sharing basis.

It is generally recognized, by now, that interactive CAI systems are technologically and educationally feasible; they possess capabilities that simply cannot be matched by human teachers. A computer is not bored by repetitive drill-and-practice; human teachers are. A computer can attend to the individual needs of hundreds of students at a time; a human teacher can attend to the needs of only one individual student at a time or, at best to the needs of a small, homogeneous group. A computer can present lesson material to individual students rapidly, via various automatically controlled media, and interpret individual responses rapidly; a human teacher must present a lesson, using whatever media he can arrange for, to an entire class. In the traditional classroom situation, much of a student's time is wasted--he either already knows what is being presented or he is not ready to assimilate what is being presented.

The principal liabilities of interactive CAI systems center around costs and the problem of implementing flexible programming techniques to cope with, and take advantage of, unanticipated student responses. The latter problem, in turn, is partly due to our still rather primitive knowledge of how children learn--a problem also faced by human teachers. Nevertheless, CAI systems are far from demonstrating the agility of an experienced human teacher in adapting to "new" teaching situations. This difficulty is at least as applicable to keyboard experience instruction as it is to any other instructional area.

The advanced CAI keyboard experience system described in Chapter II has the capabilities generally recognized to be needed for an "ideal" CAI system. And it is technologically feasible. Hardware for both static and dynamic visual displays exists and has an extremely rapid response time. The system also provides for computer-controlled, random-access audio storage and presentation--both music and voice; this capability is mandatory for a keyboard experience system. The state-of-the-art in the audio area is somewhat discouraging--digitized storage is extremely expensive, but has excellent response-time characteristics; random-access analog storage devices are also expensive and, in addition, have unsatisfactory response times. Some of the most encouraging developments in the visual and audio storage and presentation areas seem to be taking place in the PLATO project at the University of Illinois, although we have been unable to obtain specific data on the status and costs of the devices.

Keyboard experience is estimated to be significantly more demanding of computer processing time than verbal and textual subject areas. Also, the student station costs--electronic piano, audio display device, and visual display device--are estimated to be somewhat higher than for other CAI systems. The costs will come down significantly within the next five years. But if a CAI keyboard experience system were to be built today, the cost per student hour would be between $3 and $5. Presented below is an estimate of the cost of a configuration that would serve 15,000 students a year. This is a very ambitious configuration compared to present operational CAI systems, but costs must be spread over large numbers of students to become practicable.

1 large-scale computer system.	$1,700,000
15 mini-computers ($30,000 each)	$ 450,000
600 integrated student stations--instrumented piano keyboards and random-access audio and visual devices ($5000 each)	$3,000,000
Interconnecting hardware (multiplexers, etc.).	$ 500,000
System design, program development, and lesson materials development	$ 700,000
Total	$6,350,000
Cost amortized over 3 years (approx.) .	$2,100,000
Annual operating cost.	$ 200,000
Annual total cost	$2,300,000

For 15,000 students and 36 hours of instruction per student per year, the above represents a cost of about $4.25 per student hour. Once equipment and other initial costs have been paid off, costs obviously go down sharply--perhaps to around 40¢ a student hour. However, this figure makes no provision for lesson improvement or equipment replacement. Direct teacher intervention in this system would be minimal--the system would complement other music instruction given by human teachers.

It is impossible to state how accurate the above calculations are. In our judgment, they are on the high side rather than on the low side: if a major design effort were undertaken, it is possible that costs would be found to be lower. It is unlikely, however, that the costs would go below $3 per student hour, using a 3-year amortization period.

These costs do little to suggest the desirability of proceeding immediately with the full-scale development of an interactive CAI keyboard experience system. Instead, deferred feasibility is indicated. But over the long term, the economics of the situation are much brighter. And the potential educational gains are great. Included in Chapter IV are recommendations on how best to proceed to arrive at an economically feasible system.

F. An Alternative Non-Computer-Based Keyboard Experience System

The high costs of the present keyboard experience program in Wichita and the traditional non-individualized classroom setting in which it is operated, coupled with the untried technology and expected high costs of CAI keyboard systems, led SDC to explore non-computer-based alternatives. It seemed possible that imaginative innovations could be devised which would be educationally sound, which could be economically implemented on a meaningful scale right now, and which would, in addition, be compatible with CAI's emphasis on individualized learning.

The non-computer-based system described in this section is rooted in the diverse and substantial body of knowledge accumulated during the present study; it owes much to observations made of Wichita students during Task VII feasibility testing and to discussions with Wichita public school personnel, The Wurlitzer Company, and consultants to the project. The system is an expression of faith in the ability of children to accomplish much of their learning independently or in small groups, with the aid of an "automated teacher" and high-quality lesson materials. It also holds as central the educational value of having children improvise and experiment on their own.

The proposed system is simple in concept, permits individualized learning, and is economical. More importantly, based on Task VII observations and subject to confirmation through extensive trial operation, it promises to be markedly more effective than the present Wichita keyboard experience program. The costs (which are covered later in this section) are such that the system can be realistically implemented by sizable numbers of school districts--and on a meaningful scale within those school districts, not on just a token or experimental basis. In SDC's view, the principal requirements for implementation in any school district are: (1) commitment to a keyboard experience program as an integral part of a total music program in elementary schools; and (2) advocacy of educational innovations along lines such as those recently established by the Arts and Humanities Program within the U.S. Office of Education.[1]

The key elements of the system are high-quality, imaginatively structured, and empirically tested lesson materials; and highly reliable easy-to-use equipment. The equipment configuration consists of electronic pianos, headsets, cassette tape recorders, and lesson-material files. The lesson materials are comprised of prerecorded cassettes and hard-copy visuals keyed to the cassettes. Also included in the system design are blank cassettes so that students, as their abilities and interests permit, can record and play back (to themselves or to their class) their own compositions, class-developed compositions, or music learned from their keyboard experience lessons or other music environments. The availability of cassette player-recorders would also make possible vocal recordings and narrative material.

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[1] Arts and Humanities Program Bulletin, U.S. Department of Health, Education, and Welfare/Office of Education, January 1970.

The cost analysis for this system is based in part on the same factors used to calculate the costs of implementing the present Wichita keyboard experience program throughout all elementary schools in the city (100 schools, 2 third-grade classes per school, and a total population of 6,000 third-grade students). To provide each third-grade student in the city with two half-hour keyboard experience lessons per week, 120 blocks of time must be available each week at each school (60 students X 2 lessons per week = 120). If 12 half-hour blocks of time can be used each day for lessons, a minimum equipment configuration of two electronic pianos, earphones, cassette recorders, and instructional files per school is required (12 blocks per day X 5 days X 2 equipment sets = 120).

However, providing each school with only two pianos, etc., would almost certainly lead to significant scheduling and instructional problems. To establish a workable, social, and relaxed atmosphere surrounding the keyboard lessons, a minimum of three and perhaps even four or more piano sets should be provided in each school. Figure 25 shows cost estimates for some of these options.

There are a number of ways in which these estimated costs could be reduced. One would be in developing lower cost electronic pianos. (For a discussion of this possibility, see Section G of this chapter.) Another would be to share the costs of lesson development, testing, and production among several school districts (or even better, nationally). And it should not be overlooked that furnishing three or more pianos per school, for third-grade students alone, would lead to under-utilization. Thus, scheduling for third-graders could be confined to either the morning or the afternoon, instead of being spread over the entire school day. With that utilization factor, the equipment could also be put to other uses. Students in higher elementary grades could use the pianos for more advanced music-concept training; the pianos could be made available during "free time," noon hours, and after-school hours; and the pianos could be used for occasional adult education classes as

	Equipment Sets Per School		
Cost Items	2	3	4
Initial Equipment			
Pianos @ $400	$ 80,000	$120,000	$160,000
Cassette Player-Recorders @ $60	12,000	18,000	24,000
Lesson Files @ $20	4,000	6,000	8,000
Blank Cassette Files @ $10	2,000	3,000	4,000
EQUIPMENT TOTAL	$ 98,000	$147,000	$196,000
Lesson Development, Testing, and Production	60,000	60,000	60,000
TOTAL INITIAL COST	$158,000	$207,000	$256,000
Initial Cost, annualized over 3 years (per year, approx.)	53,000	69,000	85,000
Initial Cost, annualized over 5 years (per year, approx.)	32,000	41,000	51,000
Annual Operating Costs			
Electricity, supplies, maintenance	4,000	6,000	8,000
Instructional supervision	18,000	18,000	18,000
TOTAL ANNUAL COST (3 year basis)	75,000	93,000	111,000
TOTAL ANNUAL COST (5 year basis)	54,000	65,000	77,000
Annual cost per school (5 year - 3 year basis)	540-750	650-930	770-1110
Cost per student-hour (5 year - 3 year basis)	25¢-35¢	30¢-43¢	35¢-50¢

Figure 25. Cost Estimates for Non-Computer-Based System (100 Schools, 6000 Students)

part of a community-centered school environment. In short, many other productive uses could be found for the equipment, all of which would lower the cost per student hour.

It would be short-sighted to think of the proposed method of instruction being used for third-graders only. Logically, the method should continue through the fourth, fifth, and sixth grades, and perhaps beyond, at least for those children who show interest and aptitude. If student numbers were to be thus increased, cost factors would come down somewhat, since equipment could be used on more nearly a full-time basis. However, this type of student increase would also require the development of entirely new lesson materials.

Since electronic pianos require little space and playing is "silent" (students listen over headsets), the equipment could be located in a classroom, a library, a music room or an activity center without disturbing other activities.

A major premise of this system that effective learning can take place with the aid of an "automated teacher" (lesson presentation on prerecorded cassettes). Thus, the lessons would be of uniformly high quality in all participating schools. Under no circumstances do we see any need for the regular presence of a music specialist during lessons. The optimum role of present keyboard experience teachers (for example, the teachers in the Wichita keyboard experience program) would be as system managers and consultants shared by all schools. With empirically tested lesson materials (using elementary-school students to try out and iteratively modify the materials during the developmental process) and instructions narrated on cassettes and presented on hard-copy visuals, we believe that a minimum of teacher intervention would be required. As stated earlier, this system is viewed as an integral part of a total music program. In that context, students can carry back problems they experience to their other music-program environments and get them resolved; a regular classroom teacher, indoctrinated into the system, could perform this task. In this system environment, opportunities also exist for a student to receive help from his fellow students.

If active supervision or monitoring of the system is considered either desirable or necessary by a school district, no-cost or low-cost alternatives should be implemented. Students from higher grades--especially those interested in and accomplished in music--could serve as peer tutors. Volunteer adults could be enlisted on a part-time basis. Practice teachers could be enlisted. Finally, paid teacher aides could be used. For third-grade student coverage, a teacher aide could be made available on a half-day basis at an estimated cost of $1800 per year ($10 per day). In summary, the burden of instruction falls on the automated teacher; if the learning must be monitored or supervised, it can be done with older children or adults who are acquainted with the purposes and methodology of the program but who are not necessarily highly skilled in teaching music.

No costs for space have been included because the requirements are minimal and we believe the equipment, in most cases, can fit into space already available in a school.

A principal failure of many past self-instructional systems--both manual and computerized--has been the inferior quality of the lesson materials. The relatively high costs projected for lesson development must be incurred if the system is to be viable. All materials should be of the highest quality and reflect the best thinking regarding learning and media. They should also be used in personalized, humanizing ways. The estimate of $60,000 is based on the following factors:

1. Developing and testing, with students, 100-150 five-minute lesson segments, each covering a single subconcept leading to mastery of a more general concept. Estimated cost: $40,000.

2. Master recording and duplication of cassettes. The 100-150 lesson segments postulated in the previous paragraph can be recorded on twenty-five C30 cassettes (approximately 15 minutes of audio can be recorded on each side of a C30 cassette). The total number of duplicate cassettes required would be:

   100 schools x 6 student stations x 25 cassettes = 15,000.

   Based on information from a professional recording studio, the cost of recording and materials (including the 15,000 duplicate cassettes) would be approximately $17,000. This does not include a narrator and pianist; we have assumed that they would be drawn from personnel engaged in lesson development.

3. Art production and printing of hard-copy visuals. An average of 2 visuals per lesson segment is estimated, or a total of 200-300 visuals. Estimated cost: $3,000.

Blank cassettes for student use and reuse have already been separately itemized. In the system, each student would be furnished with a blank cassette to use as he sees fit.

An additional and probably worthwhile cost would be to furnish commercially available listening cassettes to each school.

It is beyond the scope of this Phase I study to formulate the operational methodology to be used in the system; this formulation is part of a Phase II developmental process. (For example, whether or not lesson segments should contain instructions to the student to stop the recorder at prescribed intervals in order to practice on the keyboard or, instead, contain built-in blank time on the tape for that purpose is a matter best determined through actual development and empirical testing.) Useful guidelines for developing the lesson content are contained in Chapters I and II.

The principal defect of the proposed non-computerized system is the absence of immediate independent evaluative feedback to the student. During trial operation of the system with students, an assessment can be made of student mastery of the music concepts presented, thus establishing the probability of successful performance in an operational environment. The interplay between students and their regular classroom teacher or music specialist also affords a means for subjective assessments of system performance. But it will still be desirable to periodically test students--both to reassure them and build their confidence that they are making good progress and to enable the school district to determine that the system is performing up to expectations. The Wood-Boardman test and similar tests, or tests encompassing an integrated music program in which keyboard experience is a part, can and should be periodically administered.

The lesson materials for this system, no matter how expertly developed, should not be considered to be cast in concrete. Fundamental musical concepts may perhaps be immutable, but instructional techniques are certainly not. Overall, the lesson materials can be expected to have a long useful life. However, improvements should be systematically sought and (when justified) incorporated. The modular lesson concept established herein facilitates making such modifications economically.

G. Electronic Piano Costs

The instructional and technical advantages of electronic pianos (or electronic organs) are obvious: a student can learn in a multi-piano environment without disturbing or being disturbed by other students; two or more students can play in ensemble without disturbing other students; and tuning is rarely required.

One factor inhibiting widespread adoption of keyboard experience programs in public schools is the cost of electronic pianos. (Other factors relate to the peripheral status of music instruction in the schools, and in particular to the status of keyboard instruction.) Implementation of a keyboard experience system on a wide scale would be promoted by substantially reducing this cost. The quality of the musical instrument, of course, must be maintained; and if it is to be used successfully in schools, it must be highly reliable and durable. The Wurlitzer piano, for example, has proven itself over a number of years in Wichita--maintenance requirements have been minimal. Although we have, in this report, used a three-year amortization period for distributing the cost of equipment, the average life of an electronic piano is comparable to that of a good-quality conventional piano--10 years to a lifetime.

We believe there are six possibilities for reducing the cost of an electronic piano:

1. Greatly increased demand, with resultant increased competition.
2. Reduction of the number of keys (to three or four octaves).
3. Use of a common tone generator and amplifier instead of self-contained tone generators and amplifiers.
4. Elimination of the foot-pedal mechanism.
5. Use of a portable table-top cabinet instead of a floor-length cabinet.
6. Reduction in component costs through advances in technology.

In a piano configuration for automated instruction, a further cost reduction would be made by eliminating the teacher's console, thereby also reducing some of the inter-connecting cable costs.

It seems reasonable that, with the above changes, the cost of each instrument might become $350 or perhaps even lower. Yet the instrument would be admirably suited to the purpose of learning musical concepts in an individualized environment. If the demand is there, we have no doubt that such an instrument can and will be built.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Comparative Feasibility of Five Keyboard Instruction Systems

This feasibility study was defined as a Phase I effort out of which would emerge recommendations either for continuation of the work under a Phase II plan, for abandonment of the work because of infeasibility, or for a statement of deferred feasibility. The conclusions and recommendations we have drawn will be vastly encouraging to those who believe in action now and a continuation of action-oriented research, and disappointing to those who believe that computerization offers instant solutions to educational problems.

A basic fact is that in spite of their great potential value, keyboard experience programs are not commonly found in elementary schools. One thing that seems to be vitally needed is an appreciation by school boards, administrators, and communities of the tremendous advantages of a keyboard experience program in acquiring a fundamental understanding of music. Put very simply, children love it; they can learn quickly, and they can be assisted toward success in other subjects. Why? We believe it is because keyboard instruction is a very humanizing experience in which a child is an active participant. The thrust of our conclusions and recommendations is to point out how these humanizing keyboard experience programs can be implemented on a meaningful scale in elementary schools over the next decade; conversely, there are paths that, in our opinion, should not be followed.

In this project, we have analyzed ways of using the newly evolving technology of computer-assisted instruction to bring keyboard experience programs to large numbers of elementary school children. We were led to give particular consideration to three computer-based systems, which we have called "IMS", "MUSIC-MAN", and "Advanced CAI". To establish a baseline, we also examined in detail the present keyboard program of the Wichita public schools. And we conceptually designed and analyzed a fifth system--an automated but non-computer-based alternative which appears to offer distinct and present advantages over the other four systems considered.

Our conclusions and recommendations for these five approaches are presented in the remainder of this chapter. Figure 26 provides a simplified synopsis.

Conclusions and Recommendations / Keyboard Instruction System	Technical Feasibility	Educational Feasibility	Economic Feasibility	Action Recommendation
1. Present Wichita Program	Is being carried on.	Has some value.	Costs are high and cannot be significantly reduced.	Do not consider for widespread implementation.
2. Instructional Management System (IMS)	Can be implemented.	Limited value for music education.	Low costs can be achieved.	Do not consider for widespread implementation.
3. "MUSIC-MAN" & 4. "Advanced CAI"	Can be implemented.	High value.	Present very high costs will come down within 3-6 years to a feasible range.	Consider for eventual widespread implementation. Continue action-oriented R & D.
5. Automated, Non-computerized System	Can be implemented.	High value.	Present costs can be very low.	Begin immediate development for early widespread implementation.

Figure 26. Simplified Synopsis of Conclusions and Recommendations

B. Feasibility of the Present Wichita Keyboard Program

It would be infeasible to implement Wichita's present experimental keyboard experience program on a comprehensive scale because of costs. These costs, conservatively estimated to be $2.00 per instruction hour per student, can be expected to increase because the major cost component is salaries. Even if the costs could be supported, there is reasonable doubt that a sufficient number of teachers could be found who possess the qualifications considered necessary by the Wichita public schools. There is also a reasonable doubt that the labor pool needed to transport the vans could be provided on a city-wide basis; the present incumbents are full-time employees of the school system who "take time out" from their regular work to transport the vans.

The program has clearly demonstrated its value in its present setting. The teachers in the program are skilled and dedicated. And the program rightfully enjoys the enthusiastic support of the Wichita community. Nevertheless, opportunities for individualized instruction are minimal, and a more cost-effective alternative should be considered for implementation on a wide scale.

C. Instructional Management System (IMS)

In our judgment, this computer-based system is inappropriate for keyboard experience instruction. It is the least expensive computer-based system available at the present time. Versions of it have been and are being successfully demonstrated in a number of schools, and SDC itself has developed and operated such systems. But all these efforts, to our knowledge, have been confined to five-day-a-week core subject areas such as reading and arithmetic, for which intensive, fine-grained testing of carefully delineated behavioral objectives appears to be of great value. Since music lies largely in the affective or aesthetic domain, there is genuine doubt in our minds that real musical experiences would be successfully fostered in an IMS environment. IMS appears to be well suited to measuring cognitive aspects of learning; certainly it provides teachers with more precise knowledge of student progress in that respect than has hitherto been available. But we judge music to be essentially an aural experience that can be more successfully acquired in a less rigorous, more experiential environment. There is no doubt, however, that the development of more precisely defined music behavioral objectives--a cornerstone of an IMS system--would be highly useful. We believe this effort should be made as part of a sustained research and development program leading to an interactive CAI system, which is the subject of our next recommendation.

D. Interactive CAI Systems

The MUSIC-MAN and the advanced CAI systems described in this report have great potential. Technological feasibility is beyond doubt, and educational institutions at all levels have expressed interest in such systems. From our study of the costs, however, such systems are clearly insupportable at the present time--least of all for elementary schools. Looking ahead, it would appear that such systems will first become economically feasible at the college level. It can also be argued that colleges are logical starting places for innovative and improved methods, since better training of teacher candidates in music concepts, through keyboard experience, would soon have a follow-through effect on children in the public schools. But such systems would be useful at all educational levels. The computer is the most effective tool yet invented for arranging the stimulus-response-reinforcement contingencies which make up learning interactions.

Our conclusion is one of deferred feasibility: these interactive CAI systems for keyboard instruction are technically and educationally feasible now, but will not be economically feasible for another three to six years. We recommend that a sustained experimental research and development effort be made over at least the next three years. This effort should focus on those aspects of an interactive CAI system that are unique, or relatively so, to the learning of musical concepts through keyboard experience. We consider it unnecessary and uneconomical to duplicate other CAI experimentation being carried out for non-musical applications. However, it will of course, be important to continually monitor the state-of-the-art of other ongoing CAI efforts, as well as technological and cost breakthroughs in hardware.

Listed below are four areas of research and experimentation that are central to keyboard experience CAI, and which we recommend be explored. These investigations should be action-oriented; that is, they should focus at all times on the desired goal of an economically feasible, educationally valuable instructional system.

1. Computer-to-piano keyboard interface technology.

2. Computer programs for analyzing piano keyboard responses and for developing keyboard lesson materials.

3. Behavioral objectives and learning strategies appropriate to computer-assisted music experience instruction.

4. Random-access audio devices.

The recommended funding level is $100,000 a year for the next three years. This research and experimentation, coupled with anticipated technological and cost breakthroughs in computers and computer-controlled visual storage and presentation devices, should result in a capability to specify a highly effective interactive CAI system for keyboard experience that can be built and operated as an experimental installation by around 1975.

E. Automated, Non-computerized Keyboard Experience System

The alternative non-computer-based system described in Chapter III, Section F, of this report meets all feasibility requirements for early implementation in elementary schools. We believe it should be immediately developed and tested on a trial basis as an independent Phase II effort. The proposed system is far less costly than the Wichita keyboard experience program and, through individualization of instruction, promises to be considerably more effective. This latter contention can be tested beyond reasonable doubt by conducting trial operations over one semester or one full school year with a representative group of third-grade students. Accordingly, we have established an implementation plan and schedule which calls for a 12-month cooperative effort involving the Wichita public schools, The Wurlitzer Company, SDC, and selected consultants.

As part of this effort, we also recommend that an equipment configuration study be made leading to the specification and prototype construction of a self-contained "music experience console." Such a console would efficiently meet the requirements of the proposed non-computerized system in an operational environment. As indicated in Chapter III, Section G, it is probable that a lower-cost keyboard can be produced that will satisfy all functional requirements. It is equally probable that integration of the keyboard, a cassette player-recorder, and possibly a synchronized audio-visual capability into a self-contained music experience console would constitute the most cost-effective equipment configuration. If attainable at a cost of no more than $500, and if proved reliable and easy to use, such a unit would be a superior alternative to the configuration outlined for trial operations (separate keyboard, cassette player-recorder, and hard-copy visuals).

The estimated cost of carrying out the foregoing recommendation is $70,000, assuming the loan of electronic pianos or other instruments by The Wurlitzer Company at no charge and the furnishing of a classroom facility by the Wichita public schools at no charge.

1. Development Plan.

a. Design, develop, and produce music-concept lesson modules for the third grade, using a team comprised of an education systems analyst, a music educator consultant, and part-time graduate college students who are preparing to become music educators.

b. Test and iteratively modify the lesson modules, using two third-grade classes (approximately 60 pupils) as the experimental group. Equipment requirements for testing include six electronic pianos, cassette player-recorders, and lesson files.

c. Study the requirements for, produce specifications for, and build and test a prototype self-contained music experience console.

d. Produce a final report of all findings, including specifications and detailed costs of implementation for an operational configuration that can be readily installed in elementary schools.

2. Development Schedule. See Figure 27.

F. Final Remarks

The foregoing recommendations constitute a program of both research and action--research because of the tremendous potential of an interactive CAI keyboard experience system, and action because improvements in music education are possible today and needed today. "The children whose childhood opportunities for education can never recur--cannot now wait upon research."[1]

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[1] "Education--'The Key to Survival'", The Washington Post, October 28, 1969, p. A18.

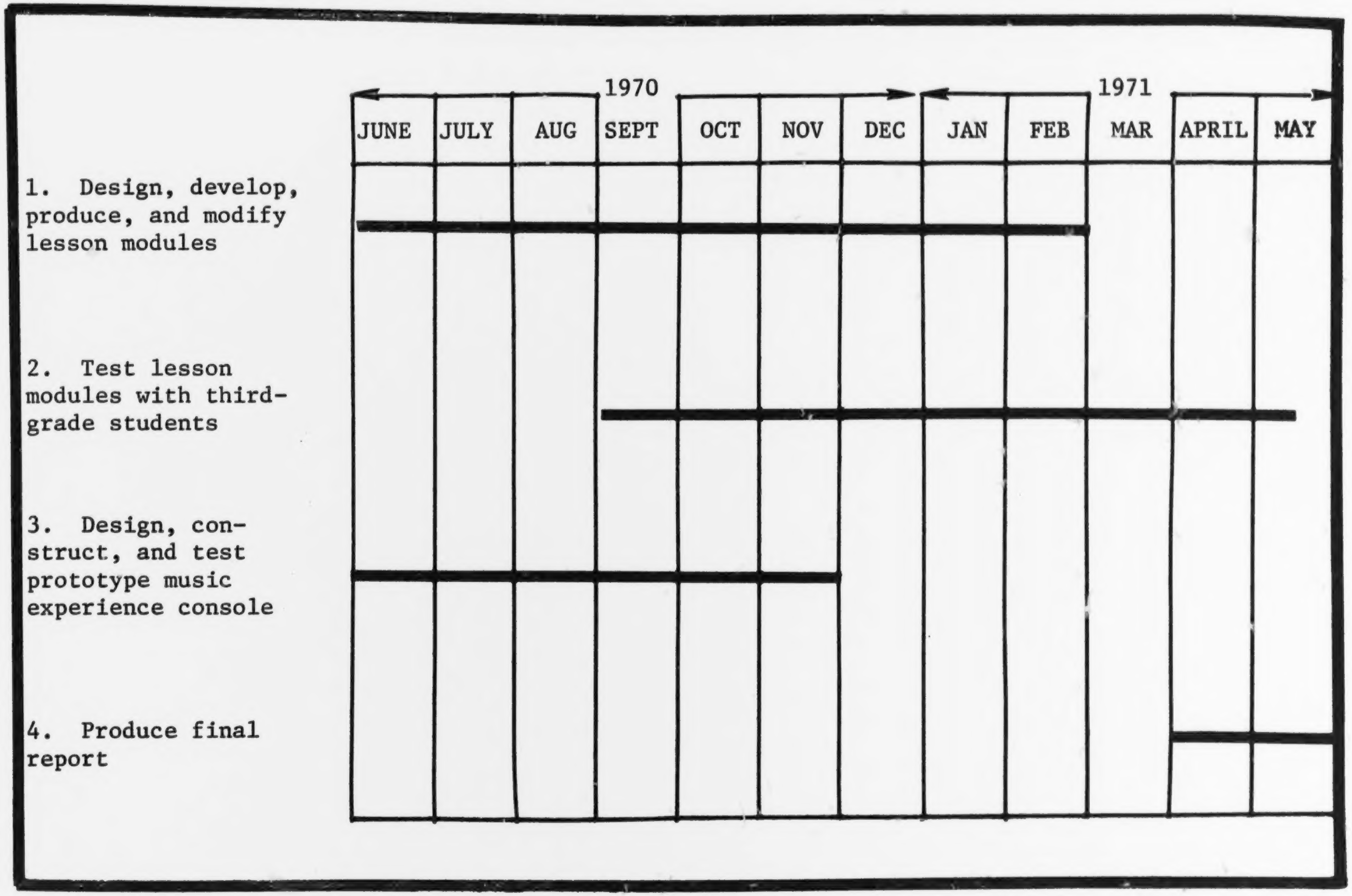

Figure 27. Schedule for Non-Computerized System Development and Testing

APPENDIX A. FLORIDA STATE MUSIC EDUCATION SPECIFICATIONS[*]

5.7410 ***Music–Elementary–Grades 1-6–***

(1) Goals–

(a) Music is one of the primary expressions of every culture. It is a functional art, a fine art and a science. As such, it must be creatively cultivated, skillfully mastered, emotionally appreciated and intellectually understood. Music wisdom is not born from the acquisition of simple skills or the development of rote motor responses, but evolves from experience, judgment, thought, and intrinsic concern. It must be experienced in its totality. Thus, attempts to conceptualize music learnings must be conceived within these limitations.

(b) Schools operating on a middle school or ungraded program may arbitrarily assign these objectives to their program at the beginning of the year provided. all stated objectives are encompassed in the total program.

(c) The structure of levels in the content section are based on percent of school population achieving stated objectives.

(d) Music in the school should enable each student to:

1. develop his creative and expressive natures
2. find satisfaction and meaning in a musical experience
3. develop skills to express his emotions through music
4. exercise music judgments
5. experience musical sensitivity
6. increase his understanding of the world, its cultures (with emphasis on his own) through a comprehension of the expressive elements of music and their interaction with elements of society.

(e) Students at all levels recognize music as a symbolic form of expression that is greater than the sum of its parts.

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[*] Furnished by the Florida State Department of Education.

(2) Instruction–

(a) Students can demonstrate music performance, listening and creative skills appropriate to their grade level and maturity. This is interpreted to include:

1. **Creativity**–(level 1) At least 60% of the students can create
   a. original interpretations to listening experiences
   b. original bodily responses to musical compositions
   c. original melodies
2. **Creativity**–(level 2) At least 75% of the students can create items listed in 1. a.–c.
3. **Creativity**–(level 3) At least 90% of the students can create items listed in 1. a.–c.
4. **Sing**–(level 1) At least 60% of the students can demonstrate the ability to sing melodies and harmonies with a pleasing quality of voice and a demonstrated realization of the importance of blend, balance, intonation, and expressive characteristics.
5. **Sing**–(level 2) At least 75% of the students can demonstrate the ability listed in (a) 4.
6. **Sing**–(level 3) At least 90% of the students can demonstrate the ability listed in (a) 4.
7. **Verbalization**–(level 1) At least 60% of the students can demonstrate the ability to discuss music performed or heard using musical vocabulary.
8. **Verbalization**–(level 2) At least 75% of the students can demonstrate the ability listed in (a) 7.
9. **Verbalization**–(level 3) At least 90% of the students can demonstrate the ability listed in (a) 7.
10. **Music reading**–(level 1) At least 60% of the students can demonstrate the ability to translate simple musical notation into sound and to recognize sound patterns in visual representation.
11. **Music reading**–(level 2) At least 75% of the students can demonstrate the ability listed in (a) 10.
12. **Music reading**–(level 3) At least 90% of the students can demonstrate the ability listed in (a) 10.
13. **Discrimination and skill**–(level 1) At least 60% of the students can demonstrate the ability to choose appropriate instruments, such as autoharp, bells, simple rhythm instruments or band and orchestral instruments, where applicable, for performing melodies or accompaniments and to demonstrate competence in performing such with at least one.
14. **Discrimination and skill**–(level 2) At least 75% of the students can demonstrate the ability listed in (a) 13.
15. **Discrimination and skill**–(level 3) At least 90% of the students can demonstrate the ability listed in (a) 13.

(b) Students can distinguish the intellectual processes involved in musical experiences appropriate to their grade level and maturity. This is interpreted as:

1. Comprehension—(level 1) At least 60% of the students can demonstrate the ability to identify the organizational elements of music, including fast, slow, beat, accent, rhythmic regularity and irregularity; pitch direction; repetition, variety and contrast in thematic treatment; simple forms, such as two- and three-part songs, rondo, theme and variation; and obvious stylistic differences of major periods and eras.
2. Comprehension—(level 2) At least 75% of the students can demonstrate the ability listed in (b) 1.
3. Comprehension—(level 3) At least 90% of the students can demonstrate the ability listed in (b) 1.
4. Value judgments—(level 1) At least 60% of the students can demonstrate the ability to discriminate quality in music performance and composition according to his own standards, but with an awareness of those standards history and society have accepted as desirable music practices.
5. Value judgments—(level 2) At least 75% of the students can demonstrate the ability listed in (b) 4.
6. Value judgments—(level 3) At least 90% of the students can demonstrate the ability listed in (b) 4.
7. Perception—(level 1) At least 60% of the students can demonstrate the ability to differentiate between individual instrumental sounds and combinations of sounds and discuss the significance of orchestration in the total musical experience.
8. Perception—(level 2) At least 75% of the students can demonstrate the ability listed in (b) 7.
9. Perception—(level 3) At least 90% of the students can demonstrate the ability listed in (b) 7.
10. Conceptualization—(level 1) At least 60% of the students can demonstrate the ability to identify the 4 basic qualities of musical sounds (duration, pitch, timbre, and dynamics) and evaluate their contribution to any specific musical experience.
11. Conceptualization—(level 2) At least 75% of the students can demonstrate the ability listed in (b) 10.
12. Conceptualization—(level 3) At least 90% of the students can demonstrate the ability listed in (b) 10.

(c) Students shall reflect a continuing growth in their understanding and expression of life and of the role music can play in their life experiences. This is interpreted to mean:

1. **Attitudes**—(level 1) At least 60% of the students reflect self-confidence in their approach to, and demonstrate a desire for, musical activities and music learning situations.
2. **Attitudes**—(level 2) At least 75% of the students reflect the attitudes listed in (c) 1.
3. **Attitudes**—(level 3) At least 90% of the students reflect the attitudes listed in (c) 1.
4. **Application**—(level 1) At least 60% of the students seek opportunities to apply music to other learning situations and respond with enthusiasm to the use of music in adjunctive learnings.
5. **Application**—(level 2) At least 75% of the students seek the opportunities listed in (c) 4.
6. **Application**—(level 3) At least 90% of the students seek the opportunities listed in (c) 4.

(d) Curriculum is constantly revised and updated with a view to providing the best experiences possible for the greatest number of students. All programs operate within a framework of long-range plans. This includes:

1. **Curriculum**—(level 1)
   - a. Curriculum shall be structured on a guide which identifies scope and sequence of musical experiences. This guide is developed locally.
   - b. Every child has music as a regular, sequential part of his weekly experience in the classroom, not only in its adjunctive uses but also in a structure learning experience that contributes to his musical growth.
   - c. In-service experiences are provided on a regular basis for classroom teachers involved in the music teaching situation.
   - d. Budgetary responsibility is evidenced in each school.
2. **Curriculum**—(level 2)
   - a. A continuous planned program of in-service education is implemented for all teaching personnel involved in the music program.
   - b. Band or orchestral instrumental instruction is available in the intermediate grades for all students desiring it.
   - c. Music specialists are actively involved in each classroom on a weekly basis.
3. **Curriculum**—(level 3)
   - a. Items in level 2 plus a continuous evaluation for in-service program and curriculum guide is implemented with written revisions of the guide at not more than 3 years intervals.

b. The musical experiences provided meet the diversified interests of students, develop musical leadership in able students, and move consistently toward higher standards.

c. All music instruction takes place during the school day.

(e) Evaluation—(level 1) Standards in the evaluation section as stated in 5.643 have been applied annually to this area in the evaluation of the stated goals for music and specific objectives identified for music offered in the school.

(3) Personnel—

(a) Method—(level 1)

1. **Departmentalized plan**—For schools in which a special music teacher is responsible for the daily planned developmental music program, the music teacher is responsible for not more than 17 classrooms.
2. **Cooperative plan**—For schools in which a special music teacher introduces, coordinates, and plans for evaluation, but in which actual responsibility for the music program is jointly shared by the music specialist and the classroom teacher, the music teacher provides a written plan for weekly instruction, is responsible for not more than 50 classrooms, and with the classroom teacher, team—or cooperatively, teaches each class at least once a week.
3. One person from among the general supervisory staff or from the music specialist staff is responsible for county-wide coordination of curriculum and given time in the school day to fulfill that responsibility.

(b) Certification—(level 2) Each teacher in music holds a valid rank III or higher certificate at the elementary level covering music.

(c) Method—(level 2)

1. **Departmentalized plan**—Teacher is responsible for not more than 13 classrooms.
2. **Cooperative plan**—Teacher is responsible for not more than 35 classrooms.
3. A musically-trained teacher serves as district-wide coordinator of music curriculum with not less than ½ time assigned for this duty.

(d) Method—(level 3)

1. **Departmentalized plan**—Teacher is responsible for not more than 9 classrooms.
2. **Cooperative plan**—Teacher is responsible for not more than 25 classrooms and with the classroom teacher, team—or cooperatively, teaches each class twice weekly.
3. A musically-trained, full-time elementary music supervisor is assigned to coordinate and implement the district-wide music curriculum.

(4) Materials and equipment—

(a) Piano and textbooks—(level 1)

1. **Piano or organ is available for all music classes.**
2. State-adopted textbooks are available in sufficient quantity for each student in a regularly scheduled music class utilizing a textbook approach.

(b) Equipment—(level 1) At least 4 of the items listed below, including 9 and 12, are provided for use in the school's music program.

1. One set of 2½ octave chromatic bells per class
2. One set of tone bells per class
3. One autoharp per class
4. One set of pre-wind instruments per school
5. One set of rhythm instruments per class
6. One set of cardboard keyboards per class
7. One set per school of text-related records for textbooks in use
8. One set of Spanish rhythm instruments per school
9. One portable high-fidelity record player per school
10. One high-fidelity tape recorder per school
11. One set (6 or more) of social instruments (guitar, ukelele) per school
12. Recorded music suitable for listening experiences at each level
13. One set of instrument charts per school
14. One set of supplementary texts per school
15. Reference books and music scores to meet the needs of teacher
16. Enrichment books are available in central library.

(c) Equipment—(level 2) At least 8 of the items listed above in (4) (b), including 7, 9, and 12, are provided for use in the school's music program.

(d) Equipment—(level 3) At least 12 of the items listed above in (4) (b), including 7, 9, 12, and 14, are provided for use in the school's music program.

(5) Facilities—

(a) Facilities—(level 1) Each school provides:

1. A music office for the music specialist large enough to accommodate a piano, necessary equipment for classroom programs and conferences with teachers and pupils.
2. Access to a space suitable for rhythmic activities and other reasonable special music activities.

(b) **Facilities**—(level 2) Each school provides a music room suitable for meeting the largest class for special music activities not adaptable to classroom conditions.

(c) **Facilities**—(level 3) Each school provides an acoustically treated, adequately and quietly ventilated room, which permits a minimum of sound transmission of interfering noises, available daily to each class for a minimum of 30 minutes daily including changes.

APPENDIX B. KEYBOARD TEACHING-LEARNING ACTIVITIES

BY
PERSONNEL OF THE WICHITA PUBLIC SCHOOLS

1. Put on head sets and adjust for proper fit. Remove and replace on hanger.
2. Turn piano on and off.
3. Discover black and white keys.
4. Discover black key groupings.
5. Play all groups of two black keys.
6. Play all groups of three black keys.
7. Discover high and low.
   a. Play high and/or low groups.
   b. Play upper key of two black keys.
   c. Play bottom key of two black keys.
   d. Discover center group of black keys.
8. Imitate finger numbers of right hand (hold up).
9. Apply fingering one, two, and three of right hand to center three black key group.
10. Teacher's hand in air, sings slowly finger numbers to "Hot Cross Buns" while students play proper tones of three black group, using right hand.
11. Refer to chart to visualize finger pattern they are experiencing. (Also use line notation.)

3 3 3
2 2 2 2 2 2 2
1 1 1 1 1 1 1

12. Sing finger numbers as they play "Hot Cross Buns" with right hand. (This will continue through succeeding lessons until appropriate rhythm and tempo is achieved.)

(For slower students or students whth coordinative difficulties, various exercises dictated by teacher and played by pupils, for example, any one finger on middle key of center three black key group, may be used as extra drill. Teacher may introduce various note durations or rhythm patterns here, as well as using accompanying chords.)

13. Discover that D is always the white key between the two black key group.

14. Locate and play all D's.

15. Starting with left hand low, play all D's using alternate hands.

16. Using second finger right hand on D, discover what key should be played by the third finger. Repeat with first finger. "What are the names of these keys?"

17. Play "Hot Cross Buns" on these new keys.

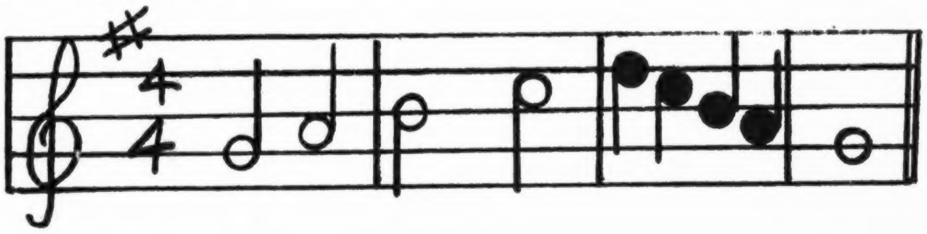
18. Using the procedure of #16 above, discover F and G with 4th and 5th finger of right hand.

19. By placing thumb on G, discover a new hand position.

20. Play "Hot Cross Buns" in this new position.

21. Review the five finger numbers of right hand.

22. Starting on G, play the following by imitation (hereafter called "Tune Up"):



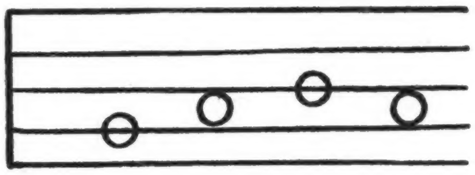
23. Transfer "Tune Up" to left hand.

24. Introduce the musical staff composed of five lines and four spaces.

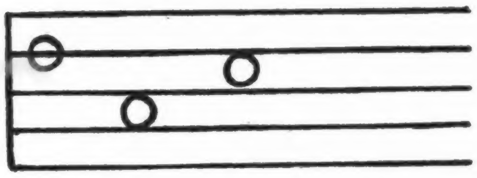
25. Draw notes in the spaces. (Hereafter referred to as space notes.)

26. Draw notes on the lines (hereafter referred to as line notes).

27. Identify through written exercises the difference between line ("L") and ("S") space notes using all lines and spaces. For example:



"L" "S" "L" "S"

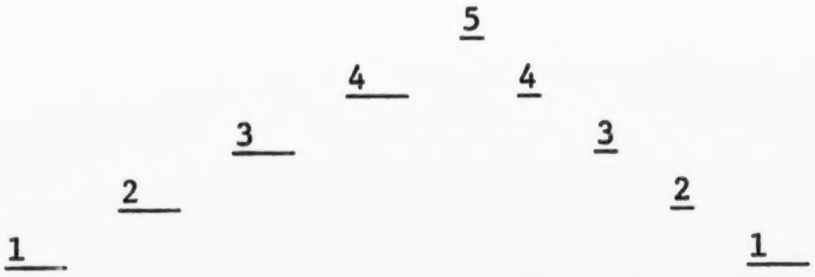


"L" "S" "S"

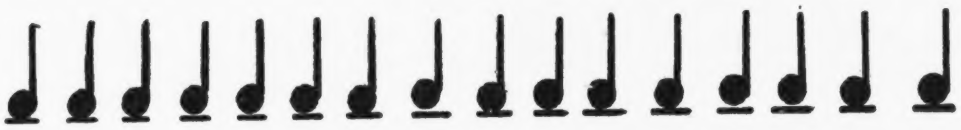
28. Review this procedure each lesson until thoroughly mastered.

29. Introduce rote piece. (Five finger piece for RH ("Love Somebody" in key of C). Apply previously learned concepts in teaching this piece.

30. Discover that not all tones in "Tune Up" are of the same duration. Show duration as follows:



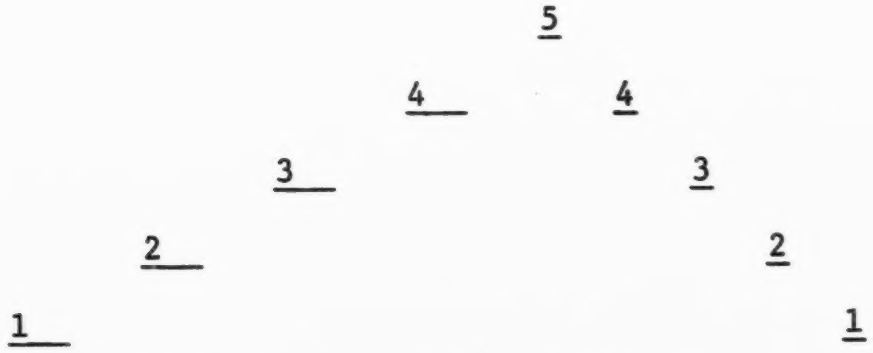
31. Show how similar notes in a piece would tend to have the same duration. For example, a piece composed of all quarter notes would look like this:



...and would sound like this: Play the above rhythm by using clapping and drum beats to simulate the above rhythm.

32. Show how the half note is used to indicate a tone held twice as long as a quarter note.

33. Apply the quarter and half note notation to show the duration of notes in "Tune Up".



34. Discover the whole note and its relationship.

35. Discover the need for a black key when playing "Tune Up" in the key of D (the D major five-finger position). Use both left and right hand, but not at the same time, to play "Tune Up" in D major. Play rote pieces with RH in this new key position.

36. Teach new rote piece, "Go Tell Aunt Rhodie".

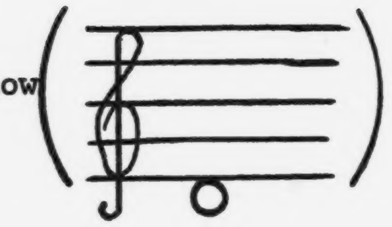
37. Show how "Tune Up" looks on the staff in C and G major, but not at the same time. Discover that from one line to the next space shows that one step is indicated. (Use C position for discovery and G position for reinforcement.)

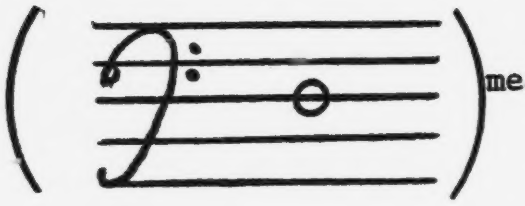
38. Discover how notes going up scale-wise look, then down scale-wise; then up skip-wise, then down skip-wise.

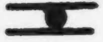
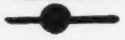
39. Show "Tune Up" in the key of D using the sharp sign in front of the F note. Discover the use of the sharp sign and how the black F (F#) is used in place of the white F. Point out the treble clef sign. Play with RH in D.

40. Introduce the names of notes in the treble staff by referring to the chart which indicates lines and spaces and their letter names. This should be reviewed periodically until completely mastered.

41. Show "Tune Up" in key of D for left hand. Introduce the bass clef sign. Compare the treble and bass clef notation for "Tune Up" in D major. Introduce Grand Staff.

42. Discover or show how  means a particular "D"

and how  means a different "D".

43. Transpose "Tune Up" to the key of E major. Play with both hands but not together. Play rote piece in RH in E major hand position. Reinforce that  is a particular E; also  . Reinforce the use of the sharp sign.

44. Review the C major five-finger key position in LH. Play 5 3 1 3 5 3 1 3 5. Then play 1 as a chord. Introduce the
3
5
terms "I chord in key of C" and "C chord". Teacher plays the melody to "The Farmer in the Dell", "Are You Sleeping", and "Row, Row, Row Your Boat" as examples of I chord accompaniment. Have pupil play I chord with LH while teacher plays the melody.

45. Repeat #44 (above) in G major and D major.

46. Review rote pieces in C in right hand, play I chord in left hand as in #44 above. Discover the need for another chord.

47. Introduce the V_7 chord in C. Transpose to G and D. Show how, in playing the V_7 chord, that the little finger of left hand moves down to the very next key.

48. Discover C scale by playing all the white keys from middle C to the C above middle C. What does this sound like? (Do, re, mi) Pupils sing Do, Re, Mi as they play it. Next sing letter names as they play the scale.

49. Discover new scale beginning on D. Reinforce need for black keys (F# and C#) as previously experienced in five finger hand position to make it sound like Do, Re, Mi.

50. Introduce E scale as above.

51. Show notation for five finger rote piece in key of F in treble clef. Discover how to find F in the treble clef. Introduce the use of the flat sign (♭) in the key of F. Point out that the black key is a B flat and not an A sharp because of custom of using a different letter for each note in the scale.

52. Introduce the F scale.

53. Discover other notes on the treble clef staff. Use three, four, and five finger note patterns as note reading experiences; preferably use segments of familiar themes such as "Three Blind Mice" or "Hot Cross Buns" (mi, re, do) or "Here Comes the Bride" $\left(\begin{matrix} & f\ f\ f \\ c & \end{matrix}\right)$ or "Tune Up" (do, re, mi, fa, sol).

54. Expand right hand reading experiences to longer phrases and begin to transfer these phrases to left hand notation.

55. Apply key of F notes to I and V_7 chords. Play melody of rote pieces in key of F and then use the I and V_7 chord accompaniment to the rote pieces.

56. Play the melody of the five-finger rote pieces in minor tonality. (Teacher use the IV minor triad for the V_7 when playing chord accompaniment, except perhaps in the final V_7 to I). Use proper notation to show this. Analyze the difference in sound between major and minor I chords and major and minor tonalities. Apply all previously learned concepts to minor keys such as notation, step relationship, sound, etc.

57. Introduce some pieces in whole tone tonality. Have pupils make up and play original accompaniment.

58. Introduce pentatonic tonality preferably on five black keys. Student creates own accompaniment. Transfer to white or combination of white and black keys through notation. (Apply previously learned concepts to pentatonic keys).

Additional items to be considered are:

1. Time signatures
2. Key signatures
3. Names of chords (C major and G minor)

4. Writing simple chords
5. Rhythm exercises
6. More work on line notation

APPENDIX C. RELATIONSHIP OF SPECIFIC AND GENERALIZED OBJECTIVES

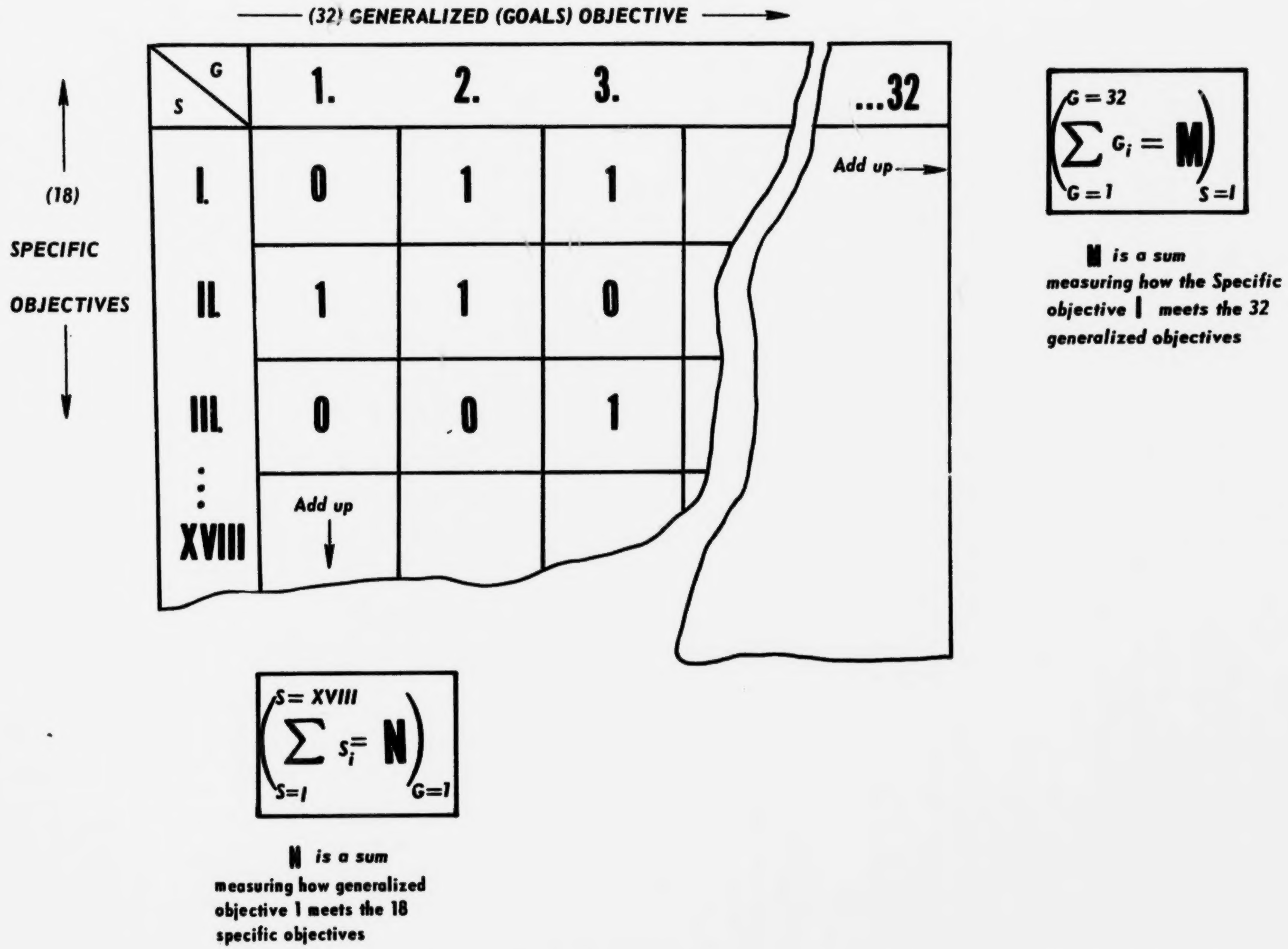
The Music Education Department of the Wichita Public Schools, in developing a Keyboard Experience Program for elementary music instruction, identified two sets of instructional objectives. These sets of objectives are considered a basic framework, resulting from curriculum development work.

First, there is a set of 32 general objectives of keyboard music instruction, as listed along the top of Figure 29 below. These general objectives define experiences, activities, teacher actions, and instructional outcomes that make up explicit keyboard experiences. The 32 objectives are probably considered to represent the instructional potentials that may be gained, via the keyboard, throughout a pupil's elementary school instruction and perhaps beyond. They comprise a set of idealized goals, plausibly attainable from keyboard experience; thus they are broad in scope and extend beyond the objectives of grade level and the specification of individual pupil attainment.

The Wichita Keyboard Experience curriculum also embraces a set of 18 specific objectives, listed at the left side of Figure 29. These relate more closely to the actual class work done by third grade pupils in the present keyboard experience. The 18 objectives have been defined as an operational set of keyboard activities and they are used as guidelines in lesson planning. These objectives do not seem to represent the objectives for single classes or individual pupils; rather they form a framework for keyboard experiences extending over a year's work. (See Chapter II, Section B.)

It is possible to relate these sets of objectives in a matrix, and such a matrix has been developed showing the apparent emphases of general objectives with respect to specific objectives and the reverse. Figure 28 indicates the matrix methodology used, and Figure 29 shows its results for the Wichita objectives.

Consider Specific Objective I: "Knowledge of Classroom Proceedings." This specific objective may be compared to each of the 32 generalized objectives. If a curriculum analyst believes the specific objective meets the intent of a particular general objective, then a tally mark is placed on the diagram at the coordinated location. An absence of tally indicates a doubtful or marginal relationship. M represents a sum, formed by adding up the tallies horizontally. Thus M measures how a given specific objective fits the set of general objectives, 1 through 32.



(32) GENERALIZED (GOALS) OBJECTIVE
(18)
SPECIFIC
OBJECTIVES
G
S
1.
2.
3.
...32
I.
II.
III.
XVIII
0
1
1
1
1
0
0
0
1
Add up
Add up
$\left(\sum_{G=1}^{G=32} G_i = \mathbf{M}\right)_{S=I}$
M is a sum
measuring how the Specific
objective I meets the 32
generalized objectives
$\left(\sum_{S=I}^{S=XVIII} S_i = \mathbf{N}\right)_{G=1}$
N is a sum
measuring how generalized
objective 1 meets the 18
specific objectives

Figure 28. Relationship of Generalized and Specific Objectives (Methodology)

RELATIONSHIP OF GENERAL & SPECIFIC OBJECTIVES ⇨ GENERAL OBJECTIVES ⇩ SPECIFIC OBJECTIVES	G1 Follow movement (up, down, repeat, skip, etc.) of simple song	G2 Name & build scale (C,F, G major) from 5 note sequence	G3 Identify major or minor mode on hearing song	G4 Show difference between whole and half step	G5 Know third, fifths, sixths, and octaves	G6 Know difference between tempo and rhythm	G7 Clap out eve or uneven rhythm pattern	G8 Point out 2–1 or 3–1 relationships in song	G9 Name simple musical styles (waltz–3/4, lullaby – 4/4, etc.)	G10 Distinguish between sounds of different chords. Recognize major and minor I chords	G11 Apply change of chords when needed.	G12 Name major and minor I chords on hearing	G13 Form major scale through step and half–step relationship	G14 Point out beginning and ending of phrase	G15 Distinguish between like and different phrases	G16 Determine rhythm pattern in twos or threes on hearing	G17 Give example of rondo, song and trio forms	G18 Demonstrate awareness of changes in dynamic level and tempo	G19 Point out treble and bass clef, grand staff, note and rest symbols	G20 Show where notes move in steps, skips or are repeated	G21 Play higher notes for, 'up' and lower notes for 'down'	G22 Play songs by note with correct tempo for class ensemble	G23 Play parts in ensemble	G24 Echo rhythm patterns of teachers	G25 Play five–note pieces using all five fingers	G26 Improve in manual dexterity without tempo loss	G27 Work from different keys avoiding middle C approach	G28 Play I, IV, and V chords in several keys	G29 Use legato and staccato touch	G30 Compose original songs	G31 Devise accompaniment for simple songs	G32 Work out melody and/or accompaniment for familiar songs	SUM (M)
Knowledge of classroom procedures I																																	0
Knowledge of keyboard (high/low, loud/soft, etc.) II	1																				1												2
Clap hands in rhythm of display pattern III						1	1																										2
Play an easy song from memory IV																																	0
Name any note on either clef V																																	0
Identify intervals on keyboard or display VI					1																												1
Name and identify function of any symbol VII																			1														1
Chant in rhythm song in 2/2, 3/4, 4/4, 6/8 meter VIII						1																											1
Play all notes with same name IX																																	0
Play 2 notes of 1–1, 1–2, 1–3, 3–1, 2–1, value on display X								1																									1
Play I, IV, V, chords in key of C, F, G XI										1																		1					2
Chord accompaniment; to own singing melody XII											1											1	1								1		4
Play accompaninent or melody in duet XIII											1											1	1										3
Play scales C, F, G major, A, D, E minor & identify whole & half stop XIV				1																													1
Build C, E, F, G scales on hearing 5–6 note sequences XV		1											1																				2
Know flat and sharp when asked number step (3rd, 4th) of scale XVI																																	0
Name scale–wise and up or down skips in songs with music XVII																				1													1
Play phrase, given music & number (1st, 2nd, etc) XVIII														1																			1
SUM (N)	1	1	0	1	1	2	1	1	0	1	2	0	1	1	0	0	0	0	1	1	1	2	2	0	0	0	0	1	0	0	1	0	

Figure 29. Matrix of General Versus Specific Objectives

The process of relating a particular general objective to the set of 18 specific objectives is quite similar. If general objective 1 ("Following melodic movement of a simple song") is tallied with respect to each of 18 specific objectives then a vertical column of tallies results. Let the letter N represent this sum. Then N measures how a particular general objective is developed by the specific objectives within a course or curriculum design.

The matrix chart shows a comparison of general and specific objectives and displays the two measures (M and N) of the extent of relationships among the objectives. These results should be considered illustrative, rather than representing a final judgment on the merits of objectives. The preliminary indications are that further development of objectives for keyboard experience may result in a program of instruction with significant internal consistency of general and specific objectives.

A recommendation for curriculum improvement includes the following:

1. The preparation of an internally consistent set of keyboard experience program objectives, with periodic review as an integral component.

2. Establishment of flexible child-centered behavioral or other evaluatable objectives to guide the daily progress of individualized instruction.

3. The development of lesson plans, including supporting materials, based on the program objectives and particularly on functional use of flexible and continually evaluated methods, techniques and materials.

APPENDIX D. SAMPLE CLASSROOM NOTES TAKEN BY SDC OBSERVER

Class 1 (April)

T = teacher; C = class; S = individual student; O = observer

T: Let's play the F scale today. Look in your books and find the starting note of the F scale.

O: Scale is on page 9 of the Schneider book. At this point, the teacher displayed a Vugraph of the F scale on the grand staff.

T: Why do we go in the middle of the keyboard?

C: (Vague, mumbled responses.)

T: Because our voices are in that range.

T: What black key is there in the F scale?

C: B flat! (chorus of answers)

T: Use right hand (RH) and put five fingers on first five notes of scale.

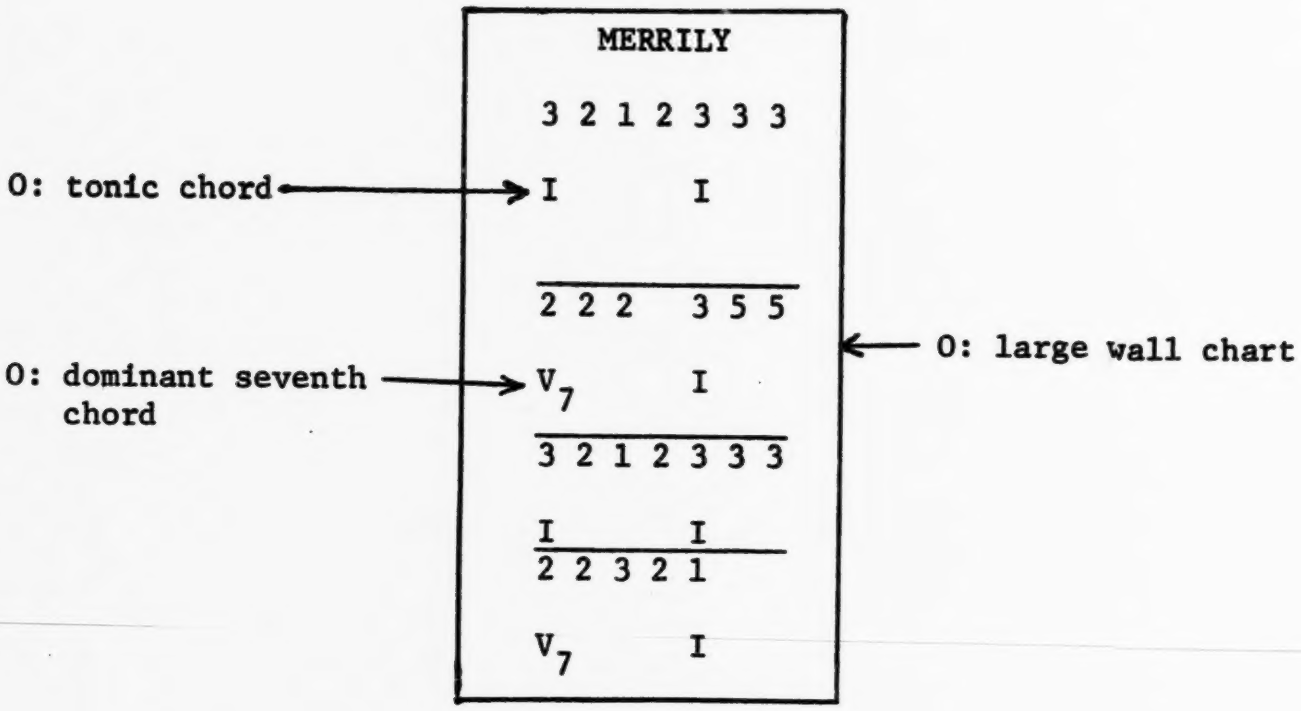
O: Teacher then proceeded to number first five notes in red, on the Vugraph, and then around the classroom to check students' finger positions. He then played the melody and chords for "Merrily We Roll Along." Next, he referred the class to a wall chart of "Merrily" (see below) which shows the fingering, and had the class play the tune (melody only) in the F scale.

T: Next, use left hand (LH) to play F chord (fingers, 1,3,5). Follow along with me and play the chord when I do.

O: Teacher then played several tunes and had class play the chord "in time" with the music, following him.

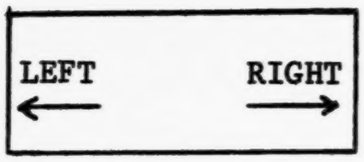
T: Using LH, find the five Ds on the keyboard. Find all the Es. Find all the Cs. How many Cs are there?

C: Six (not a chorus, but there were some correct replies).


MERRILY
3 2 1 2 3 3 3
I I
2 2 2 3 5 5
V7 I
3 2 1 2 3 3 3
I I
2 2 3 2 1
V7 I
O: tonic chord
O: dominant seventh chord
O: large wall chart

T: Which is your left hand (to one boy)? Remember, if you don't know which is your left hand and your right hand, look at the chart on the wall.

O: Wall chart is reproduced below:



O: At this point, the teacher started to put on a Vugraph, but the bulb for the projector was burned out.

O: This was a good class (comment to teacher).

T: It's a high third-grade class (comment to observer).

Class 2 (April)

T = teacher; C = class; S = individual student; O = observer

T: This is a tough class--a low fourth-grade class (comment to observer).

T: Turn to page 7 of the Pace book.

O: Teacher spent time getting students to finger the C tonic chord, using LH and RH. Told class to put RH on middle C (counting fingers 1,2,3,4,5). He had the class raise LH and identify finger numbers. He called out the finger numbers and the class "showed" fingers one by one. The class had quite a struggle identifying finger numbers.

T: Play the C chord with your LH. What do you do with your 2nd and 4th fingers?--you hold them up, or the chord won't sound right. Don't hold your fingers out straight. Bend them, like this.

O: Teacher demonstrated, with own fingers, the way to bend fingers and hold up the 2nd and 4th fingers.

T: What is the chord we're playing called?

C: C chord (lots of wrong answers, however).

O: Teacher went around classroom checking while students practiced playing the chord.

T: Now play the three high Cs. Use LH over RH. Now play them in rhythm while I play.

O: Teacher played "Down in the Valley" while the class played the three high Cs in 1-2-3 rhythm.

T: Take off your headphones and turn your speakers on. Now play the three high Cs again.

O: Teacher played same tune and class played three high Cs. Sound filled room. Students enjoyed this greatly. Sounded great even though several students weren't able to keep time, but played the Cs randomly.

T: What was the name of the tune?

C: "Down in the Valley."

O: Above exercise was repeated, but in the D scale (students playing 3 high Ds). Teacher had students look on page 1 of the Schneider book to find the Ds.

T: Now play the low C on your piano; now play the low F.

O: Ran out of time at this point; low C and low F shows up in later class notes.

Class 11 (May)

T = teacher; C = class; S = individual student; O = observer

O: Teacher displayed Vugraph of "Riddle Song," color coded for LH and RH. He had students, in groups of three, play it with speakers on, per Vugraph fingering.

T: Open to page 2 (of Schneider book). How many can play "Hot Cross Buns" with both hands?

O: Teacher told those of class who'd been in program 2 years to try both hands; others, use 1 hand. Several did it reasonably well with 2 hands; hadn't played it for about a year, per the teacher. Those who played it did so with speakers on so rest of class could hear. Teacher went up and down aisle checking.

T: Find 3-2-1 notes to "Hot Cross Buns," starting with any black key.

O: Most students were able to do it.

T: Play and sing numbers to "Merrily" (3-2-1-2-3-3-3, etc.). Use white keys.

O: Teacher then sat at his piano and played accompaniment and sang numbers to demonstrate playing and rhythm.

T: I'll have individuals play melody of "Merrily" while I play the chords.

O: Did so.

T: Play the 3 high Cs while I play "Down in the Valley."

O: Did so. Repeated for 3 high Ds. Teacher heard someone playing other than Ds and asked:

T: Where is D on keyboard?

C" (Everyone seemed to know.)

O: Foregoing was done in both headphone and speaker modes.

O: Teacher then played United States Marine song. Had class play two top B flats in beat time. He came to a part of the song and asked:

T: Why can't you play B flat for that part?

S: Not right rhythm (not accepted).

S: Not black notes (not accepted).

T: Because the chord won't match!

Comments to Observer

T: How about something that lights up the keys (lights or moving lights, for example) for drill. Drill becomes very boring to a teacher.

T: How will computer handle color coding?

T: I don't worry about hands spanning an octave at this age. Five-finger position is what we stick to.

T: At the PTA concert, had 2 electronic pianos and 24 students. Tried to pick students who have no outside piano lessons or other instrumental lessons.

Class 12 (May)

T = teacher; C = class; S = individual student; O = observer

T: Practice playing "Merrily."

O: Class did so.

T: Play the 3 high Cs while I play "Down in the Valley."

O: Class did it quite well. When teacher wants to hear 1 student at a time and class is already in speaker mode, teacher listens over speaker instead of through the communication center. He went around the class and had everyone play the 3 high Cs because he heard someone playing the wrong notes. Students tend to play the 3 high Cs faster and faster with each repetition, losing timing. Teacher stopped them when that happened, told them what they were doing, and continued.

T: Find the low C and low F. Play them while I play "Down in the Valley."

O: Did so.

T: Girls play 3 high Cs; boys play low C and F. Then switch. I'll play "Down in the Valley."

O: Did so, very well--a few too fast.

O: Teacher put Vugraph of "The Western Yodeler" on, which shows color-coded fingering of beat (L 232, etc.). He then used the communication center to listen to students practicing the beat individually. Then he played the entire tune and sang the lyrics while the students played the beat. Following this (same Vugraph) had class learn the Db-Bb ostinato for "The Western Yodeler." He went up and down the aisle checking. Took several minutes. Then he played the tune while the class played the ostinato, first through headphones, then over speakers and singing:

Rid ing Home
over and over
Db Bb Db

He had some individuals do it with their speakers on to check them. First time this class had done this.

T: Don't use pedals in these classes. But if a student in the class is taking piano lessons and has advanced to that stage, he can use pedal (comment to observer).

Class 13 (May)

T = teacher; C = class; S = individual student; O = observer

T: Here is a Vugraph of "The Western Yodeler." Sort of a boogie beat.

O: Teacher went through same exercise as in other classes (L 232, etc.). He listened to individuals practice through the communication center. In this mode, when he talks to an individual, others can hear his voice "indirectly," i.e., not through microphone but just because he is speaking in the same room.

T: Class, when I'm listening to individuals, you should be practicing. Don't wait for me to get around to you before you starting playing.

T: Now we'll have the girls do it, then the boys, with speakers on. Boys--put your hands behind your head so you won't be tempted to play when the girls are playing.

O: Some played well; some played randomly, i.e., not in beat.

T: Now we'll have the students on the left side play the L 232 and students on the other side play the Db, Bb. I'll play the entire tune. Speakers on.

O: About the same results. Again, students really enjoy this exercise.

Teacher Comments to Observer

T: Smaller classes tend to get better grades because I get to spend more time with them individually.

T: I visualize, in computer setup, having pianos facing wall so I walk behind students to check them.

T: Example of time problem: just handing out a worksheet, having class do them, and collecting them takes 15-20 minutes. A computer could do part of a worksheet one day, more the next.

T: Takes about the first half of the year before a class can play together in ensemble without it being a shambles; so I don't use that mode very much.

Appendix E. Attendees at Keyboard CAI Design Meeting

31 July-1 August
Falls Church, Virginia

Dr. Raynold Allvin, San Jose, California
Miss Judith L. Cherrington, U.S. Office of Education
Dr. Ned Deihl, Pennsylvania State University
Mr. Arthur Harrell, Wichita Public Schools
Mr. Tyndall Ice, The Wurlitzer Company
Dr. Walter Ihrke, University of Connecticut
Dr. Gerald Lefkoff, West Virginia University
Dr. Paul Lehman, University of Kentucky
Mr. John Schneider, Wichita Public Schools
Dr. Joseph Lipson, Nova University, Florida

SDC

Mr. Joseph Bangiolo
Mr. Walter Bellman
Dr. John Coulson
Mrs. Joye Hewlett
Mr. Michael Jacobs
Dr. William Kent
Mr. Edward Meyer
Mr. Roy Neperud
Dr. Harry Silberman
Dr. Thomas Williams

APPENDIX F. FUNCTIONAL SPECIFICATIONS FOR AN ELECTRONIC PIANO-TO-COMPUTER INTERFACE

A. Introduction

This appendix contains functional specifications for an electronic piano-to-computer interface for keyboard music instruction. These specifications are primarily for the components required for the MUSIC-MAN system. These components also represent most of the hardware that must be specially designed for an advanced CAI and, hence, these specifications should be partially applicable to it. Design considerations have been discussed in the body of the report; therefore, this appendix presents primarily functional specifications.

B. General Specifications

1. Electrical and Logical. No computer has been selected for these systems. Therefore, specifications presented here assume that compatibility with the selected computer is obtained. Important requirements are electrical compatibility such as logic voltage, logic power, timing and rise time requirements, and logical compatibility such as communication and I/O signal requirements.

2. Mechanical. This equipment is for use with young curious children, among others. Therefore, care should be taken to insure its mechanical integrity, maintainability, and safety. For instance, fragile components, such as display tubes, should be protected. Interchangeable items such as labels on lights, should not be removable by students. Any potentially dangerous voltages should be inaccessible and should remain so even if cases or enclosures are broken. These requirements are an important consideration in component selection.

C. Keyboard-Computer Interface

The intent of the keyboard-computer interface is to supply the computer with knowledge of the "state" of the keyboard as it varies in time. "State" refers to the position of the keys--up or down. This information is used for student response analysis and prescription of new material. Adequate time resolution is provided if the keyboard state can be sampled every 50 milliseconds.

1. Time-Driven or Polling Interface System. In the polling system, the computer periodically interrogates the piano keyboard. The following specifications detail the functions that must be

provided by each piano or organ. In addition, any interpiano or multiple source output facilities pre-existing in the piano system must not be disturbed.

a. Each piano must be individually addressable by the computer.

b. The state of each key (up or down) must be available to the computer independent of other keys which may be depressed simultaneously.

c. The computer must be able to read the state of a group of adjacent keys (where the number of keys in a group is the number of bits in computer core) with one input instruction.

d. No anomalies, such as switch contact bounce, are permitted in the key state lines. The lines may be filtered; the allowable rise and fall time on signals is 20 milliseconds maximum.

e. The piano must always be readable by the computer. Signals changing during the read operation do not present a problem.

f. Two computer instructions, on the average, should be sufficient to read a group of keys into the computer.

g. A signal equal to the logical OR of all keys shall be provided. It may be a separate signal or it may replace a key state signal for an infrequently used key.

h. A digital signal equal to logical 1 when tones are being generated by the piano and logical 0 otherwise must be provided. As in (f) above, it may replace a key state signal. The analog threshold level used to determine the existence of tones must be adjustable to compensate for changes in noise or hum in the individual pianos. This signal must not be affected by externally generated signals. Rise and fall times on this signal must not exceed 20 milliseconds.

i. Mechanical and environmental requirements for the interface must be compatible with those of the computer used. In no case can special air-conditioning be provided.

2. State-Driven Interface. In state-driven system, the piano interface is responsible for generating a signal when a change of any kind occurs (key is depressed or released, response button is pushed, etc.) at the student piano. The specifications are similar to those of Section C (above), paragraph 1, except the following is to be substituted for subparagraph f:

> The interface must generate signal when any change occurs at the student console. Changes include: piano by depression, piano by release, response key depression (see Section D below). This signal must occur no later than 2 milliseconds after change. Rise time must be fast enough to allow leading edge triggering in the computer. The signal may either be a pulse or a level which is cleared when the interface is interrogated.

D. Student Response Panel

A response panel of push button switches is required so that the student may make non-musical inputs to the computer.

1. Eight push button switches may be required. These must be interlocked so that only one button can be pushed (or sensed logically) at a time.

2. The output of the panel can be eight lines, or a 3-bit code on 3 lines. These lines can be separate or can replace key state lines of infrequently used piano keys.

3. If used with a state driven interface system, depression of any key must produce the signal specified in Section C, paragraph 2.

4. Provision must be made for labeling the keys. The labels must be alterable, but not by the student.

E. Numeric Display Panel

A numeric display is required to indicate to the student which item or page number he should use next.

1. The numeric display panel must be capable of displaying a 3-digit decimal integer. No decimal points required. Digits should be at least 3/4" high.

2. The display should be readable under normal room lighting.

3. If possible, leading zero should be suppressed.

4. The display must retain the number being displayed and be able to display it indefinitely.

5. The display should be set from the computer in no more than 2-3 instructions. The response time of the display is not critical.

6. If the display is not mechanical, the computer should be able to turn it off so that no digits are displayed.

F. Response Light Panel

A panel of lights controlled by the computer is required to allow direct communication from the computer to the student.

1. Six to eight lights or separately displayable messages may be required. Only one will be used at any one time.

2. The input from the computer can be 1 line for each message or a 3-bit code on 3 lines.

3. When activated by the computer, light or message should be illuminated for 0.5 - 1.5 seconds and should then be extinguished automatically. A less desirable alternative is that the computer must be able to turn the lights on and off.

4. Labels on the lights or messages should be alterable, but not by the student.

5. Panel must not become hot under continuous use.

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